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USER'S GUIDE

User's Guide: Roller-Compacted Concrete Pavement

by

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The User's Guide provides the technical information required to implement the application of roller-compacted concrete (RCC) pavement. Included are details on application, benefits/advantages, limitations/disadvantages, and costs associated with this technology. Information is provided on three construction sites at Kitzingen, West Germany; Fort Drum, New York; and Hollister, California. Also provided is information concerning funding, procurement, maintenance, and performance monitoring. A fact sheet on RCC pavement, engineering technical lettter on thickness design, and a guide specification are provided in the appendixes.

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Contents

1 Executive Summary

Description

Roller-compacted concrete (RCC) pavement is a low water content (zero-slump) portland cement concrete (PCC) placed with asphalt concrete (AC) construction equipment. The RCC is mixed in a central plant, normally a pug mill mixing plant, and hauled to the construction site in non-agitated haul trucks. The RCC mixture is placed by an AC paver and then compacted with vibratory, static steel drum, and rubber-tired rollers.

Application

The use of RCC pavement is applicable to any pavement that is subjected to heavy-load or tracked vehicle traffic in maintenance, storage, or parking areas, and low-speed roadways. The use of RCC pavement on high speed areas is not recommended. Tests have shown that skid resistance can be achieved, but currently surface smoothness requirements can not be achieved with RCC pavements.

Benefits

RCC paving allows for the high-production placement of concrete without the use of large slipform pavers or forms and the consolidation, finishing, and texturing required of conventional PCC pavement. The amount of labor required is significantly less than conventional PCC pavement of the same thickness and this usually will result in cost savings over PCC.

Limitations

RCC pavement should only be used in relatively low speed applications. These applications have included material handling and shipping yards, hard-stands (tank parking areas), and low-speed secondary roadways. The surface

texture of an RCC pavement is somewhat coarser than that of a conventional PCC pavement and the surface smoothness is also rougher.

Costs

The use of RCC can result in a cost savings of from 10 to 30 percent over conventional PCC pavement construction. The cost savings are realized through the elimination of large concrete pavers and reductions in the work force by eliminating the need for finishing and texturing operations. Currently, most RCC pavements have contraction joints cut and sealed as is done with conventional PCC; however, some savings may result in that the distance between joints is normally greater for RCC pavements than for PCC pavements.

Recommendations for Use

RCC pavement is recommended for use where heavy, low-speed traffic is the primary user of the pavement. RCC pavement is also recommended for areas subjected to tracked-vehicle traffic. The available guide specifications should be followed closely, and quality construction methods should be followed at all times.

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2 Preacquisition

Description of Roller-Compacted Concrete RCC Pavement

RCC pavement is a construction procedure in which a PCC pavement is constructed using AC construction methods and equipment. The RCC is a very stiff (zero-slump) concrete mixture that is placed without forms by using an asphalt paver and compacted with conventional asphalt rollers. The consistency of RCC has been described as a wet dirty gravel (Palmer 1987). RCC construction has evolved from a natural progression of established practices involving cement-treated base (CTB) course with increased cement contents and improved aggregate materials and gradation (Piggott 1986). CTB can be differentiated from RCC by the compressive strengths achieved. CTB and other similar materials such as econocrete and dry rolled lean normally obtain compressive strengths of 1,000 psi or less, and RCC normally obtains compressive strengths of 3,000 to 4,000 psi, similar to conventional PCC (Tayabji and Okamoto 1987, Hansen 1987).

RCC pavement was evaluated by the U.S. Army Engineer Waterways Experiment Station in the mid 1970's as a construction method to utilize substandard or marginal quality aggregate materials (Piggott 1986, Burns 1976). These included applications of expedient surfaces for the military and suitable commercial applications. The first large paving application of RCC in North America was in British Columbia, Canada in 1976 (Tayabji and Halpenney 1987).

RCC pavement has been widely used for heavy load traffic in maintenance, container storage, parking, or low speed roadway applications. The development of more sophisticated paving machines designed specifically for RCC and improved construction techniques and procedures has resulted in higher quality pavements. These improvements have led to the possibility of utilizing RCC for high speed applications.

Utilization of RCC for high speed applications requires information on skid resistance and load transfer parameters. Normal surface texturing practices used for PCC are not available with RCC pavement construction. The surface texture obtained will be similar to that obtained with asphalt pavement for the blend of aggregates used. This should require high quality, crushed aggregate

to provide suitable skid resistance. The load transfer and related joint spacing are variables that need to be investigated. In its earlier stages of development, RCC pavements were typically allowed to crack naturally. In some instances sawcuts were made at obstacles where cracking would be expected to occur. These natural cracks were widely spaced, typically 30 ft to over 100 ft apart, due primarily to the low water content of the RCC mixtures.

Currently paving machines are available that have been built especially for RCC. In addition to the vibrating screed normally found on asphalt pavers, the RCC pavers have one or more tamping bars working with the vibrating screed to improve density.

Application

RCC pavements have in the past been used mainly for maintenance and parking areas or as low speed access roads. These areas have been used for low speed, heavy load, and tracked vehicles. The intended use of the pavement surface and the cost-effectiveness of RCC are normally the deciding factors in the selection of RCC over either AC or conventional PCC. Tracked or high-pressure tire traffic, especially in areas of channelized traffic, normally require a PCC pavement over an AC pavement. The cost-effectiveness of RCC is based in part on the elimination of the requirement for a large slipform paver or erecting forms and finishing and texturing operations. Test sections have been constructed in Australia, Spain, and the United States to evaluate the capabilities of RCC for high-speed roadway applications. The results of these field tests show that RCC can currently meet all normal PCC construction requirements except for that of surface smoothness. Table 1 provides a listing of some Corps of Engineers projects involving RCC pavement construction. Appendix A contains a fact sheet of RCC pavement.

Design Methods

The thickness design practices used for RCC pavement in the United States and worldwide are normally adaptations to the procedures that are used for conventional PCC pavements. Laboratory beam fatigue tests have shown that the fatigue behavior of RCC is similar to that of conventional PCC (Tayabji and Okamoto 1987). The U.S. Army Corps of Engineers (CE) design for conventional PCC uses a fatigue analysis based on stresses calculated by the Westergaard free edge load analytical model (Rollings 1987, 1988). This CE design for conventional PCC allows for a 25 percent reduction in stresses due to load transfer between slabs for airfields and parking areas. The design procedure for roads does not allow this reduction due to the proximity of the loading to the unsupported edge of the slab. For RCC, the assumption of no load transfer in the design of airfields, parking areas, and roads was made as a conservative approach to account for the wide range of crack widths and spacings normally associated with RCC pavements. Therefore, the standard

Table 1
Location of Corps of Engineers RCC Construction Sites

Location	Date	Remarks
Kitzingen, West Germany	FY86	A 16,500-sq yd tank hardstand was constructed in thicknesses ranging from 7.1 to 12.6 in. A test section was constructed over 2 days on one end of the hardstand and evaluated for required properties. The remainder of the hardstand was paved in 6 days.
Fort Drum, NY	FY88-89	Approximately 88 acres of RCC was placed over a period of 2 years. The RCC was placed to a compacted thickness of 10 in. The RCC was placed on vehicle maintenance and parking areas throughout the installation. Saw cut joints were not made at certain intervals, but were made at locations where cracks were going to occur (next to corners of existing structures, manholes, planters, and intersections). The contractor was also required to route and seal all cracks that appeared within 28 days after paving.
Hollister, CA	FY92	Approximately 1,500 ft of a haul road was paved with 7 in. of RCC pavement. The 28-ft wide roadway was placed on two different days with the longitudinal joint saw cut and approximately 6 in. of uncompacted RCC removed. Two layer construction was attempted in a small section of the pavement. A curing compound was applied to the surface rather than wet curing. Skid resistance and rideability tests were performed on the RCC pavement.

CE published design charts and computer programs cannot be used for RCC. The basic design procedure can be used if an appropriate amount of load transfer is considered. In addition to accounting for no load transfer, another consideration is the bonding of multiple layers that comprise the RCC structure. Normal maximum compacted lift thicknesses for RCC vary from 9 to 10 in. (Tayabji and Okamoto 1987, Rollings 1988). Heavy duty pavements requiring thicker sections will require construction in lifts to achieve the desired thickness. Bonding of layers or lifts can be difficult and in instances where these lifts are not satisfactorily bonded together, they must normally be considered as partially bonded layers, thereby increasing the total required thickness of the RCC pavement. Design guidance for the CE is provided in Appendix B.

Evaluations of existing RCC pavements have shown that the strength and density of the pavement is lowest at the bottom of the lift. The strength obtained at the bottom will control pavement performance because the highest stresses due to loading occur at the bottom of the slab. This should be taken into consideration when designing a RCC pavement especially where thicker lifts are required (Rollings 1988).

Materials

The aggregate gradation recommended by the CE for RCC pavement is similar to that used for AC mixtures. Some of the initial RCC mixtures used gradations normally associated with concrete mixtures (American Society for Testing and Materials 1992); however, more recently, satisfactory performance has been obtained with gradations similar to those used for AC (Hutchinson, Ragan, and Pittman 1987). RCC paving mixtures used initially in the United States contained nominal maximum aggregate sizes up to 1-1/2 in.; however the majority of RCC pavement placed today has a nominal maximum aggregate size of 3/4 in. (Pittman 1988). The smaller maximum aggregate size will help to prevent segregation and to provide satisfactory surface texture. Crushed aggregates have been used in most instances for RCC pavement mixtures (Jofre, Fernandez, Josa, and Molina 1988). Natural sands have sometimes been blended into these mixtures to meet gradation requirements. Crushed aggregates compared to uncrushed aggregates in an RCC pavement mixture are normally more difficult to compact; however, they are less likely to segregate during transport and placement (Anderson 1987, Ragan 1985, Abrams, Jackson, Norton, and Irvine 1986). When properly mixed, transported, and placed, no RCC pavement constructed with 3/4-in. nominal maximum size aggregate in a well-graded blend of aggregates has had problems with segregation or an open textured surface (Pittman 1988, Ragan 1988). The major gradation variation between RCC and conventional PCC occurs in the RCC having more material passing the No. 4 sieve and succeeding sieves through the No. 200 sieve. This additional fine material provides for an acceptable surface texture and assists in preventing segregation (Anderson 1987, Larson 1987). The fine material, if nonplastic, can reduce the amount of cementitious material required (Hutchinson, Ragan, and Pittman 1987). The material passing the No. 40 sieve should have a liquid limit and plasticity index not exceeding 20 and 4, respectively (Hutchinson, Ragan, and Pittman 1987).

Types I and II portland cement have been most widely used by the CE in RCC paving mixtures (Ragan 1988). Type IV portland cement has also been used for RCC pavement (Murphy 1987). Classes C and F fly ash have also been used in many RCC mixtures. The amounts of fly ash used by the CE have ranged from 20 to 40 percent by total weight of cementitious material (Hutchinson, Ragan, and Pittman 1987). Fly ash can be used to increase the paste volume and improve the compactability (Hutchinson, Ragan, and Pittman 1987, Ragan 1988). The majority of use has been to improve the aggregate gradation of the RCC mixtures (Pittman 1988). Other countries have made extensive use of cements with active additives and also the addition of fly ash to regular cements. These additive or fly ash components can comprise upwards of 50 percent of the weight of the cementitious material in the RCC mixture (Jofre, Fernandez, Josa, and Molina 1988). With these amounts of material replacing the cement, the rate of strength gain is lowered from those of mixtures with plain portland cement. Total cementitious material content used has varied from 11.5 to 14.5 percent by weight of dry materials (Jofre, Fernandez, Josa, and Molina 1988).

The use of admixtures in the United States have been limited predominately to RCC test sections. One of the few reported uses of an admixture on an actual project was the addition of a retarding admixture to a mixture placed on a tank hardstand at Fort Bliss, Texas (Ragan 1988). In Spain, retardant admixtures have been widely used to increase workability time (Jofre, Fernandez, Josa, and Molina 1988).

RCC pavement has been placed in climates with substantial frost or freeze-thaw cycles with no reported failures; several of these pavements have been in place for long periods of time (Piggott 1986). Studies have shown that normal nonair-entrained RCC mixtures will fail when exposed to standard freeze-thaw tests (Ragan, Pittman, and Grogan 1990). A recent study has shown that an acceptable void matrix can be developed in RCC pavement with standard air-entraining admixtures (Ragan, Pittman, and Grogan 1990). Sweden has also been able to establish an acceptable void matrix with air-entraining admixtures (Anderson 1987). The combination of the low water content of RCC, placement at a high density, and the use of a drainable base course designed to prevent water from saturating the pavement structure can provide a durable pavement even when it is exposed to cycles of freezing and thawing (Rollings 1988).

Ragan, Pittman, and Grogan (1990) found that the flexural strength of air-entrained RCC is 10 to 30 percent lower than that of nonair-entrained RCC. This is consistent with strength loss experienced with air-entrained conventional PCC. The loss in strength from the air-entraining agent can be counteracted to some extent by utilizing the water-reducing properties of these agents to reduce the water/cement ratio and thereby increase the flexural strength (Ragan, Pittman, and Grogan 1990). Limited field studies have indicated that air-entrained RCC can be constructed with current mixing and placement procedures; however, extensive testing will be required to evaluate any air-entraining admixture used in the RCC mixture and obtaining accurate measurements of air content in the fresh RCC may be difficult.

Construction Techniques

The first step in RCC pavement construction is the preparation of a base course. The base requirements for an RCC pavement are the same as those that would be used for a conventional concrete pavement (Piggott 1986). The base course must provide a solid base on which a high density RCC pavement can be placed and compacted (Rollings 1988). If the existing subgrade material is too soft to provide this solid base, a base course of suitable strength is required. The surface on which the RCC pavement is placed must provide a suitable surface for the trafficking of trucks and the paver without rutting or damaging the existing surface (Larson 1987). The underlying base must also provide enough strength to allow for the compaction of the RCC being placed and compacted on top of it (White 1986). One area of consideration is construction over a drainable base course. With proper construction methods, a conventional PCC pavement can be constructed over a drainable base course;

however, construction of an RCC pavement will be difficult on a drainable base, unless it is first stabilized to provide a satisfactory construction surface.

Mixture proportions must be developed to meet project requirements. The use of a 3/4-in. nominal maximum size aggregate should provide a suitable surface texture. Cementitious materials added to the mixture can include various types of cement and fly ash.

Mixing is normally accomplished in a continuous flow twin-shaft pugmill mixer, although other types of conventional PCC mixers have also been used successfully. The pugmill mixers offer efficiency and large rates of production normally required for RCC pavement.

Placement is normally accomplished by the use of a paver. Other methods have been used but do not provide the consistency of surface texture and improved grade and surface smoothness that is available from the paver. Pavers are the most efficient method of placing large volumes of RCC pavement.

RCC is compacted similar to AC. Normally one or two static passes with a steel-wheel roller are used for breakdown, followed by 4 to 6 passes with a vibratory roller. A rubber-tired roller then makes several passes to complete the compaction and a steel-wheel roller is used for finishing rolling to remove any existing marks made by the previous rollers. The RCC is normally placed so that only fresh longitudinal joints (equivalent to hot joints in asphalt concrete) are made during each days placement. Cold joints which occur with any break in construction, such as overnight, are saw cut either partial or full depth, and the outside 4 to 6 in. of RCC pavement is removed.

The material characteristics of the RCC mixture that affect compaction include particle size and distribution, moisture content, and layer thickness (Withrow 1988). Achieving the required density of the RCC mixture with proper compaction is one of the most important components of successful construction. The limits on lift thickness are tied to the ability of the compaction equipment available to achieve compaction. With the rollers currently available, the maximum lift thickness that can be reliably compacted is about 9 to 10-in. (Rollings 1988). Past experience has shown that the density obtained decreases with depth, thereby placing the least dense and therefore weakest concrete at the bottom of the pavement where tensile stresses are the greatest (Rollings 1988). Compaction should be completed as soon as possible to allow for achieving density and to allow curing to start, normally within 2 hr of mixing (Anderson 1987). Delays in compaction in excess of 30 minutes can result in a reduced density, especially at the joint. It has been reported that vibratory rollers normally associated with RCC compaction will not significantly effect the air-void system or the distribution of the air voids in the mixture (Ragan, Pittman, and Grogan 1990).

RCC, with its low water/cement ratio, will crack at spacings greater than conventional PCC. In some early applications, the RCC pavement was allowed to crack naturally with no joints. This was done for various reasons

including economic, application or location, and construction considerations of the RCC. Neither cutting nor sealing the contraction joints further reduced the cost of RCC construction versus conventional PCC. RCC was placed mostly in log sorting yards, heavy equipment parking and maintenance areas, and container ports. In these areas, the appearance of nonuniform random cracks did not detract from the pavements performance, even after minor spalling had occurred. In many applications, spalling or other distresses have not been a serious problem, even after 10 years of service (Piggott 1986).

Recent applications of RCC pavement have used sawed contraction joints for aesthetic reasons and to reduce maintenance. Random cracks were found to be aesthetically unpleasing when compared to the straight and uniform joint pattern that is familiar with conventional PCC pavement. Sawing RCC to control the cracking will result in an aesthetically pleasing appearance. Sawing and the subsequent sealing will also help reduce or prevent the occurrence of spalling along the joint or crack. Sawing contraction joints may actually reduce the long-term maintenance requirements and perhaps extend the serviceable life of the pavement. Current practice is moving toward sawing and sealing the contraction joints in nearly all RCC construction. The distance between sawed joints is normally twice that used for conventional PCC pavements of equal thickness.

Due to the low water/cement ratio of RCC, there is a minimum amount of free water available for curing of the pavement surface; it should not be allowed to dry or scaling of the surface could result (Piggott 1986). The surface should be kept moist at all times during the curing period; past United States construction practice with RCC has required a wet cure for at least 24 hr after placement (Pittman 1986). The wet cure can be accomplished by water spray trucks, sprinkler (fog spray) systems, wet sand layer, or wet burlap or cotton mat coverings (Hutchinson, Ragan, and Pittman 1987; White 1986). The cure method used for the remaining cure period, normally 7 days total, can be a continuation of the above methods; however, the curing can also be continued with a white-pigmented membrane curing emulsion. White pigmented curing compounds, similar to those used for conventional PCC, have been used for RCC pavement curing; however, due to the more open surface texture, the rate of application to achieve a complete seal is much greater than that for PCC. The application rate should be approximately 100 to 150 sq ft per gallon of curing compound (Piggott 1986). One project used this upper limit, applied in two coverages from different directions, and judged it a satisfactory alternative to water curing (Abrams and Jacksha 1987). However, the use of white pigmented curing compounds could invite inadequate strength gain at the surface if the compound is applied to a dry surface, if it is applied in a nonuniform manner, or if the film thickness is too thin to prevent moisture from leaving the surface of the RCC pavement.

The quality control and quality assurance methods used for RCC pavement construction are very similar to conventional PCC and AC pavement construction. Testing at the concrete plant includes testing of the aggregates for the moisture content and the desired gradation. The in-place density of RCC pavement is critical for good performance. A nuclear density gage is used

during compaction to control roller patterns in order to achieve the desired density. The readings obtained are often correlated against those achieved in a previously completed test section. Current CE guide specifications state that calibration of the nuclear gages should be made with a calibration block that is made prior to the construction of the test section. Those tests to be used for density determinations of the completed RCCP should be obtained in the direct transmission mode. Measurements taken with a nuclear gage should be compared with the wet density, because of problems involved in the gage accurately determining the moisture content of the RCC mixture (Ragan 1988). Density measurements in Spain are typically performed with a nuclear gage at a rate of one test for every 100 sq m of pavement surface (Jofre, Fernandez, Josa, and Molina 1988). The desired moisture content as determined from a modified proctor test is from the optimum down to 2 percentage points below optimum (Jofre, Fernandez, Josa, and Molina 1988). The sand cone has also been used to calibrate the nuclear gage; however, the sand cone density is most influenced by the density of the surface and the density obtained during compaction is always lower at the bottom of the lift (Ragan 1988).

The fabrication of field test specimens is used to verify that the RCC pavement meets the specified properties. Specimen preparation procedures differ from those detailed in ASTM C 192 (ASTM 1991) for normal PCC in that the mix does not have the consistency necessary to fill a beam mold with only minimum internal consolidation. Fabrication methods for test specimens of RCC mixture have not been standardized.

Appendix C contains a guide specification that can be used to construct a RCC pavement.

Limitations/Disadvantages

When properly designed and constructed, an RCC can provide an excellent pavement surface. Considering the rideability or surface smoothness currently attained with RCC, the use of RCC should be limited to areas of low-speed (<40 mph) traffic. Construction of RCC is fastest and most economical when the paving can be arranged to where only fresh joints are constructed throughout the working day. Areas where fresh longitudinal joints cannot be made require cutting back of the uncompacted edge and removal. These operations can interfere with further construction and hinder curing operations. Areas where aesthetics and rideability are important will require that sawed joints are constructed and sealed.

Life-Cycle Costs and Benefits

RCC pavement is a construction procedure which allows the optimum use of money and materials. RCC can provide a pavement that is near equivalent in service to a PCC pavement but at a lower cost.

The cost savings involved with RCC are the result of one or more of the following factors: the elimination of forms (or a slipform paver); dowels and reinforcing steel; the use of existing construction procedures, materials, and equipment; and the placement of large quantities of concrete in a relatively small time frame similar to slipform construction. Cost savings realized by the CE have varied from 10 to 30 percent or more for RCCP versus a conventional PCC pavement (Hutchinson, Ragan, and Pittman 1987; Larson 1987; Pittman 1986). Similar savings have been obtained in commercial applications with RCC versus AC or PCC options (Abrams, Jacksha, Norton, and Irvine 1986). The majority of cost savings have generally been accrued through reductions in construction costs rather than in material costs (Rollings 1988).

Cost savings in Canada have ranged from 15 to 25 percent over conventional PCC (Larson 1987). RCCP is often used as a subbase and base course in conjunction with conventional PCC and asphalt pavement, as well as a surface course with an asphalt surface treatment (Murphy 1987). Depending on the combination used, the savings have varied from 6 to 64 percent (Murphy 1987).

Initial evaluations of RCCP in the early 1970's were concerned with the ability of this mixture to use substandard or marginal aggregates to obtain satisfactory mixes (Burns 1976). This would allow the use of locally available previously rejected material (Piggott 1986).

In areas of cut and fill, due to overall thinner pavement structures for RCC versus AC, the use of RCC pavement would result in increased cost savings through lower material movement and handling (Piggott 1986). Logie and Oliverson (1987) detailed cost savings obtained with RCC versus conventional AC and PCC for heavy loads over a soft subgrade which resulted in thick pavement sections.

RCC pavement is not a new pavement construction or rehabilitation process, but an improvement in an existing, although not highly utilized, pavement construction technique. The process of RCC pavement construction being used today is proving to be cost-effective and is producing quality pavements.

Advantages/Benefits

RCC can provide a pavement equivalent to that of conventional PCC, although with lower surface smoothness, for lower construction costs. Areas where aesthetics are not important, such as sorting, storage, and container yards, can have even lower costs as the RCC pavement can be allowed to crack on its own.

3 Acquisition/Procurement

Potential Funding Sources

Typically, installations fund the implementation of pavements and railroads technologies from their annual budgets. However, the installations annual budget is usually underfunded and the pavements and railroads projects do not compete well with other high visibility or high interest type projects. As a result, it is prudent to seek out additional funding sources when the project merits the action. Listed below are some sources commonly pursued to fund projects.

a. Productivity program. See AR 5-4, Department of the Army Productivity Improvement Program for guidance to determine if the project qualifies for this type of funding.

b. Facilities Engineering Applications Program (FEAP). In the past, a number of pavement and railroad maintenance projects located at various installations were funded with FEAP demonstration funds. At that time, emphasis was placed on demonstrating new technologies to the Directorate of Engineering and Housing (DEH) community. Now that these technologies have been demonstrated, the installations will be responsible for funding their projects through other sources. However, emphasis concerning the direction of FEAP may change in the future; therefore, one should not rule out FEAP as a source of funding.

c. Special programs. Examples of these are as follows:

(1) FORSCOM mobilization plan which may include rehabilitation or enlargement of parking areas and the reinforcement of bridges.

(2) Safety program which may include the repair of unsafe/deteriorated railroads at crossings and in ammunition storage areas.

(3) Security upgrade which may include the repair or enlargement of fencing.

d. Reimbursable customer. Examples of this source are roads to special function areas such as family housing or schools and airfield pavements required to support logistical operations.

e. Special requests from MACOMS.

f. Year end funds. This type of funding should be coordinated with the MACOMS to ensure that the funds will not be lost after a contract is advertised.

g. Operations and Maintenance Army. These are the normal funds used for funding pavement and railroad projects.

Technology Components and Sources

Components of the technology which must be procured for the use of RCC pavements are section design (may be in-house or contracted out) and a contractor to perform the RCC pavement construction. RCC can be produced in conventional PCC plants; however, the type of plant used most often to produce RCC has been a continuous flow twin-shaft pugmill mixer. RCC pavement construction utilizes conventional AC placement equipment which is widely available in the pavement construction industry. AC paving machines and all types of rollers are widely available. There are pavers manufactured especially for RCC that have both tamping bars (one or two) and a vibrating screed. There are several contractors who have had at least some experience in placing RCC pavements. The CE has design guidance and guide specifications (see Appendixes B and C) and a construction practice manual (U.S. Army Corps of Engineers 1987) covering the use of RCC pavement.

Procurement Documents

Applicable specifications

One guide specification available to provide assistance in completing this project is CEGS-02520, Roller Compacted Concrete (RCC) Pavement for Airfields, Roads, Streets, and Parking Lots, Department of the Army, Corps of Engineers Guide Specification, Washington, DC, January 1988 (see Appendix C).

GSA listing

GSA listing is not applicable to this report.

Vendors list and recent prices

This list includes local contractors who have the capability.

Procurement Scheduling

Normal construction contract schedules should be established that allow adequate design and plan preparation time, design and review and approval, contract preparation, advertising and award, and construction time. A typical pavement project is designed 1 to 2 years before it is constructed; however, relatively small projects that require limited plans and specifications can be prepared and ready to go within a few months.

4 Post Acquisition

Initial Implementation

Equipment

Conventional PCC mixing and AC paving equipment can be used to produce, place, and compact RCC pavement. However, the majority of RCC mixture is produced in a continuous flow twin-shaft pugmill mixer and often the pavers employed have been specially adapted for RCC placement and contain one or two tamping bars in front of a vibrating screed. For compaction, conventional asphalt concrete rollers are used including non-vibrating and vibrating steel-wheel rollers and rubber-tire rollers.

Materials

The materials required for RCC are basically the same as those required for PCC pavement construction and will vary according to project conditions. The gradation of the aggregates used more closely follow that used for AC than for PCC. Normally 3/4 in. is the maximum aggregate particle size used in RCC pavements. RCC pavements have been constructed with pozzolans such as fly ash as part of the total cementitious material in the mixture. There are several methods with some modification that are suitable for developing mixture proportions including ACI 211.3 (ACI Committee 1992), ACI 207.5R (ACI Committee 1992), and ASTM D 558 (ASTM 1991). The CE has used a modification of ACI 207.5R to develop mix proportions. The CE has also developed a proportioning method using soil compaction methods (U.S. Army Corps of Engineers 1992).

Personnel

The personnel normally required at a PCC plant and those required for AC construction are the same as those needed for construction of an RCC pavement. Additional personnel required during construction would be for saw cut and curing operations. The quality control required for the paving can be readily handled by any commercial testing laboratory qualified for both PCC

and AC testing. The quality control testing at the demonstration projects was performed by personnel from commercial testing laboratories.

Procedure

The general procedure used to construct an RCC pavement includes the following:

a. Construct subgrade, subbase, and base course layers in a fashion similar to that used for other rigid pavements.

b. Lay out the placement pattern, when possible, to provide paving lanes of satisfactory length to allow for fresh longitudinal joints during placement.

c. Place the RCC and compact to the desired density as soon as possible.

d. Begin the wet curing of the RCC pavement, upon completion of rolling, and continue for 7 days or apply a suitable curing compound to the pavement surface prior to the surface drying out.

e. Saw contraction joints as soon as possible, but generally within 24 hr to prevent uncontrolled cracking. Later seal these joints to prevent water intrusion and their filling with debris.

Operation and Maintenance

Operations and maintenance on an RCC pavement are similar to that of a PCC pavement. If contraction joints are cut to control cracking, then there is no difference. If cracks are allowed to form on their own, then there is potential for some foreign object damage (FOD) caused by raveling and scaling that will develop at the cracks over the life of the pavement. In some uses, such as hardstands and vehicle maintenance areas, this type of distress can be acceptable. The life expectancy of an RCC pavement should be about the same as that of a conventional PCC pavement of an equal strength, thickness, and structure. Several RCC pavements have been in place for 10 to 15 years and have provided performance that would have approximated the expected performance of a conventional PCC pavement under similar conditions.

Service and Support Requirements

No special services or support is required to implement or maintain this technology.

Performance Monitoring

Installation personnel can monitor and measure the performance of the RCC pavement by making periodic inspections of the pavement for signs of distress (cracking, raveling, spalling, etc.). This monitoring of performance would be no more than that required for any PCC pavement. The performance monitoring can be adjusted to fit into existing pavement management systems. Unusual traffic or climatic conditions could adversely affect performance and should be noted.

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Appendix A
Fact Sheet

TECHNIQUE: Roller-Compacted Concrete Pavements (RCCP)

DESCRIPTION:

RCCP is a construction procedure that places a very low or zero-slump concrete mix on a prepared base course with an asphalt paver. RCCP has also been placed using a grader, dozer, or jersey spreader. The consolidation and finishing procedures are accomplished by a vibratory roller making three to four passes over the surface. This method of construction eliminates the cost of labor, equipment, and materials for forming, finishing, and form removal. This technique can be used to place large volumes of portland cement concrete (PCC) in a short period of time using minimal labor and equipment. Test sections of RCCP have proven that a hard, durable and economical pavement is produced by this construction method.

AREAS OF CONSIDERATION:

This construction procedure can be used to surface tank roads, parking, and washing facilities. RCCP provides an alternative to high maintenance cost areas for tracked vehicles (lock-wheel turns, channelized traffic, hardstands) and can be used to surface low-volume roads. RCCP can be used as base course material having a lower percentage of cement than that used for PCC pavement mixtures.

PHYSIOGRAPHIC FACTORS:

The reduction of water in the RCCP mixture accelerates the hydration process; therefore, additional attention should be given to the sequence of construction. The lower water content also limits the distance mixture can be transported from the mixing plant to the construction site. Conventional PCC pavement curing procedures are satisfactory for RCCP.

DISCUSSION AND RECOMMENDATIONS:

The concept of roller-compacted concrete (RCC) was originated in the early 1970's for use in mass concrete structures. The Corps of Engineers has successfully used RCC in several structures, the most noteworthy being the Willow Creek Dam at Hepner, OR, completed in 1982.

In 1975 the RCC method of construction was used to build two pavement test sections at the U.S. Army Engineer Waterways Experiment Station (WES). The conclusions from these investigations were favorable for the construction and use of RCCP. A very significant result of these investigations was to confirm the theory that the lower water content of the zero-slump concrete mixture reduced shrinkage, thereby, allowing the number of joints required for shrinkage to be greatly reduced in RCCP. RCCP's have been utilized in several major construction projects for both Federal agencies and commercial owners.

Compaction of RCCP is obtained with vibratory rollers. The size of the roller and the amplitude and frequency used are important factors in obtaining desirable consolidation. In addition, the consistency of the ingredients will affect the ability to obtain satisfactory consolidation. Past experience has indicated that three or four passes of the vibratory roller are necessary to produce the desired compaction.

A guide specification on RCCP (CEGS-02520) is available along with additional guidance provided in associated technical manuals TM 5-822-6 and TM 5-822-7.

This procedure was developed to produce an economical and durable surface with the importance of surface smoothness minimized. Experience has proven that an acceptable surface meeting the requirement for parking areas and aprons can be obtained by this construction method.

REFERENCES:

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Appendix B
Engineering Technical Letter

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314-1000

ETL 1110-1-141

CEEC-EG

Engineer Technical
Letter 1110-1-141

29 January 1988

Engineering and Design
THICKNESS DESIGN OF ROLLER-COMPACTED CONCRETE PAVEMENTS FOR AIRFIELDS, ROADS, STREETS, AND PARKING AREAS

1. Purpose. This letter describes the procedures used to design the thickness of roller-compacted concrete pavements (RCCP) for airfields, roads, streets, and open storage areas.

2. Applicability. This letter applies to all HQUSACE/OCE elements and all field operating activities (FOA) having military construction and civil works design responsibility.

3. References.

a. TM 5-822-7

b. TM 5-825-3

4. Discussion.

a. Roller-compacted concrete pavement is a construction method using a zero-slump portland cement concrete mixture that is placed with an asphalt concrete paving machine and compacted with vibratory and rubber-tired rollers. For additional details on properties of roller compacted concrete for pavements, see TM 5-822-7, appendix D.

b. A major difference exists in the assumptions of load transfer at joints made for conventional concrete pavements and RCCP, which directly effects the design stress and the thickness of the pavement. RCCP has typically been allowed to crack naturally, and the spacings between these cracks are usually irregular, ranging from 40 to 70 feet apart (although spacings much greater and much lower than these have been reported). Consequently, the width of the crack opening will be greater and the load transfer developed from aggregate interlock at the cracks will be highly variable, if not totally lost. Limited tests at Ft. Hood, TX and Ft. Stewart, GA, have revealed average load transfer at transverse contraction cracks of 18.6 percent (standard deviation of 6.7 percent) and 16.7 percent (standard deviation of 5.9 percent), respectively. Tests on longitudinal and transverse construction joints revealed even less load transfer. Therefore, the assumption of 25 percent load transfer at joints in open storage areas and airfields constructed of plain concrete may not be valid for RCCP thickness design. Therefore, the approach is to base the thickness design of RCCP on no load transfer at the joints, i.e., assuming all joints/cracks to be a free edge condition.

5. Action to be Taken.

a. For roads and streets, open storage areas and parking areas, the thickness design curves attached in Enclosure 1 will be used.

b. The thickness design curves for conventional concrete airfield pavement in TM 5-825-3/AFM 88-6, Chap. 3, will be used also to design RCCP airfields, with one modification. To account for no load transfer at joints in RCCP, multiply the flexural strength by 0.75, and use the product as the design flexural strength to enter the thickness design curves. This will in effect remove the load transfer assumption from the curves.

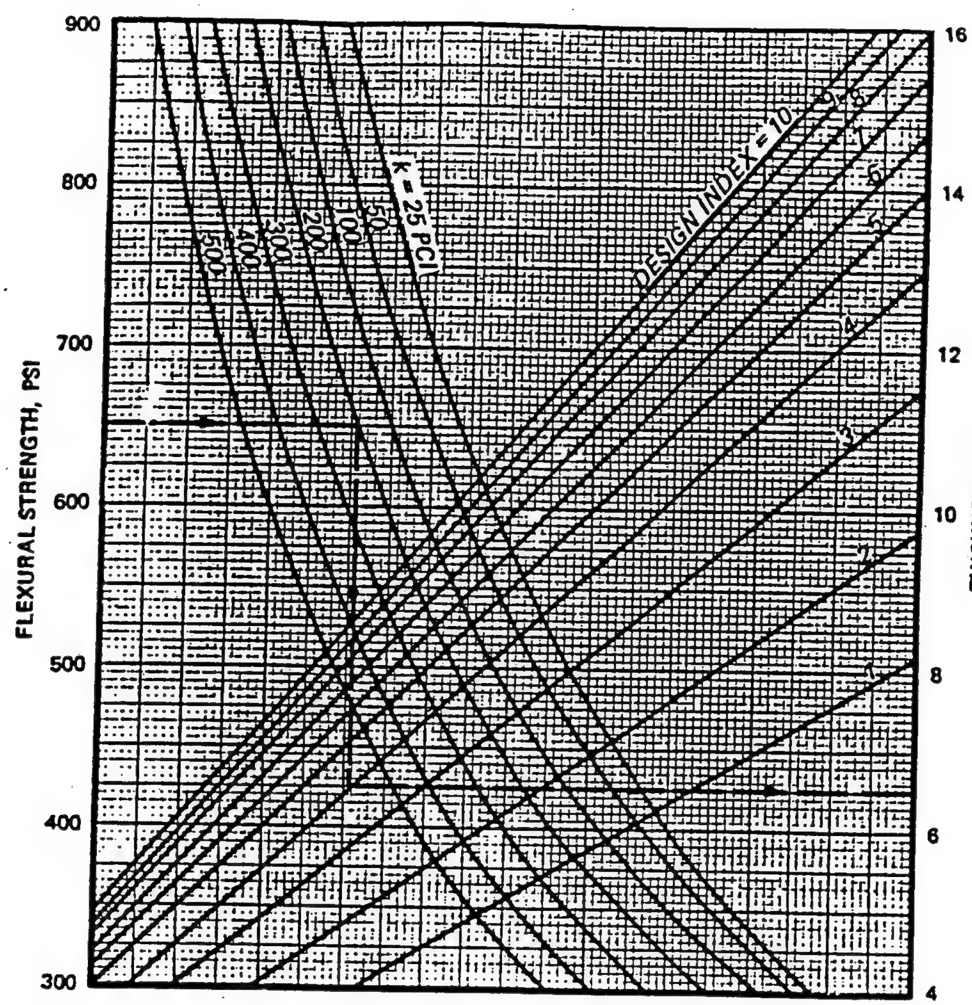
c. Transverse contraction joints, when needed, should be spaced at 30 to 60 feet, primarily to create a more aesthically pleasing and easily maintained joints. The sawcuts are typically made 12 to 20 hours or later after compaction and penetrate to one-third the pavement thickness.

6. Implementation. This letter will have routine application as defined in paragraph 6c, ER 1110-345-100.

FOR THE COMMANDER:

Encl

HERBERT H. KENNON
Chief, Engineering Division
Directorate of Engineering
and Construction



Design Curves for RCCP Roads, Streets, Open Storage Areas, and Parking Areas

Enclosure 1

Appendix C
Guide Specification for Military Construction

****
DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS

CEGS-02520 (August 1991)

Superseding
CEGS-02520 (January 1988)

GUIDE SPECIFICATION FOR MILITARY CONSTRUCTION

Includes metric Special change (September 1993)
Includes changes through Notice 3 (January 1993)

Latest Notice change indicated by \&&\ tokens

****

SECTION 02520

ROLLER COMPACTED CONCRETE (RCC) PAVEMENT
08/91

****
NOTE: This guide specification covers \@requirements for roller compacted concrete (RCC) pavements for airfields, roads, streets, parking areas, repair yards and open-storage areas@\. This guide specification is to be used in the preparation of project specifications in accordance with ER 1110-345-720.
****

PART 1 GENERAL

****
NOTE: See Additional Notes A and B.
****

1.1 REFERENCES

****
NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

\-ASTM C 33-\	(1990) Concrete Aggregates
\-ASTM C 117-\	(1990) Materials Finer Than 75-micrometer (No. 200) Sieve in Mineral Aggregates by Washing
\-ASTM C 123-\	(1983; R 1990) Lightweight Pieces in Aggregate
\-ASTM C 131-\	(1989) Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

\-ASTM C 136-\	(1984a) Sieve Analysis of Fine and Coarse Aggregates
\-ASTM C 142-\	(1978; R 1990) Clay Lumps and Friable Particles in Aggregates
\-ASTM C 150-\	(1989) Portland Cement
\-ASTM C 171-\	\&(1991)&\ Sheet Materials for Curing Concrete
\-ASTM C 174-\	(1987) Measuring Length of Drilled Concrete Cores
\-ASTM C 295-\	(1990) Petrographic Examination of Aggregates for Concrete
\-ASTM C 494-\	(1990) Chemical Admixtures for Concrete
\-ASTM C 566-\	(1989) Total Moisture Content of Aggregate by Drying
\-ASTM C 595-\	(1989) Blended Hydraulic Cements
\-ASTM C 618-\	(1991) Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete
\-ASTM C 989-\	(1989) Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
\-ASTM C 1040-\	(1985) Density of Unhardened and Hardened Concrete In Place by Nuclear Methods
\-ASTM D 1557-\	\&(1991) Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/cu. ft. (2,700 kN-m/cu. m.))&\
\-ASTM D 3017-\	(1988) Water Content of Soil and Rock in Place By Nuclear Methods (Shallow Depth)
\-ASTM D 4791-\	(1989) Flat or Elongated Particles in Coarse Aggregate

CORPS OF ENGINEERS (COE)

\-COE CRD-C 100-\	(1975) Method of Sampling Concrete Aggregate and Aggregate Sources, and Selection of Material for Testing
\-COE CRD-C 114-\	(1973) Method of Test for Soundness of Aggregates by Freezing and Thawing of Concrete Specimens
\-COE CRD-C 130-\	(1989) Scratch Hardness of Coarse Aggregate Particles
\-COE CRD-C 400-\	(1963) \&Requirements for&\ Water for Use in Mixing or Curing Concrete

FEDERAL SPECIFICATIONS (FS)

\-FS CCC-C-467-\ (Rev C) Cloth, Burlap, Jute (or Kenaf)

NATIONAL READY-MIXED CONCRETE ASSOCIATION (NRMCA)

\-NRMCA CPMB 100-\ (1990) Concrete Plant Standards

1.2 MEASUREMENT AND PAYMENT

****
NOTE: See Additional Note C.
****

1.2.1 Measurements

1.2.1.1 Concrete

The quantity of concrete to be paid for will be the number of cubic \^meters,^\ \~yards,~\ rounded to the nearest tenth of a cubic \^meter,^\ \~yard,~\ placed in the completed and accepted pavements, including the accepted test section. No measurement or payment will be made for wasted concrete or for concrete used for the convenience of the Contractor or for concrete outside the neat lines shown on the drawing. Concrete will be measured in the completed and accepted pavements in accordance with the dimensions shown in the plan and cross section. Any areas of pavement with excess thickness will be counted as having the thickness shown on the plans. No deductions will be made for rounded or beveled edges or the space occupied by pavement reinforcement, dowel bars, tie bars, or electrical conduits, nor for any void, drainage, or other structure extending into or through the pavement slab measuring 3 cubic feet or less in volume. No other allowance for concrete will be made unless placed in specified locations in accordance with written instructions previously issued by the Contracting Officer.

1.2.1.2 Cement

The quantity of cement to be paid for will be the number of \^metric tons^\ \~tons~\ of cement used in the completed and accepted pavements. No measurement or payment will be made for wasted cement or for cement used for the convenience of the Contractor. The quantity to be paid for will be determined by multiplying the weight in \^kilograms^\ \~pounds~\ of cement required by the mixture proportions per cubic \^meter^\ \~yard~\ by the number of cubic \^meters^\ \~yards~\ of the various mixtures placed and measured for payment, then dividing by \^1000^\ \~2000~\ and rounding off to the nearest tenth of a \^metric ton.^\ \~ton.~\

1.2.1.3 Pozzolan

The quantity of pozzolan paid for will be the number of cubic \^meters^\ \~feet~\ solid volume of pozzolan used as a cementitious material in the completed and accepted pavements. No measurement or payment will be made for wasted pozzolan or for pozzolan used for the convenience of the Contractor. The quantity to be paid for will be determined by multiplying the approved weight in \^kilograms per cubic meter^\ \~per cubic yard~\ of pozzolan used as a cementitious material, in pounds, in each type of concrete used by the number of cubic \^meters^\ \~yards~\ of RCC placed and measured for payment and dividing by the product of the average specific gravity of the pozzolan multiplied by \^1000.^\ \~62.4 pounds per cubic feet.~\ The average specific gravity will be the average of results of all tests, of material delivered to the project, made by the Government on samples taken prior to or during the period covered by the payment, or of similar tests made by the supplier, if

determined by the Contracting Officer to be appropriate. No measurement or payment will be made for pozzolan used strictly as a Contractor's option to compensate for lack of fines in the aggregate.

1.2.1.4 Ground Granulated Blast Furnace Slag

****
NOTE: If ground granulated blast furnace slag is not locally and readily available, remove this paragraph and all further reference to the material.
****

The quantity of ground granulated blast furnace slag to be paid for will be the number of \^metric tons^\ \~tons~\ of ground granulated blast furnace slag used in the completed and accepted pavements. No measurement or payment will be made for wasted ground iron blast furnace slag or for ground granulated blast furnace slag used for the convenience of the Contractor. The quantity to be paid for will be determined by multiplying the weight in \^kilograms^\ \~pounds~\ of ground granulated blast furnace slag required by the mixture proportions per cubic \^meter^\ \~yard~\ by the number of cubic \^meter^\ \~yards~\ of the various mixtures placed and measured for payment and then dividing by \^1,000^\ \~2,000~\ and rounding off to the nearest tenth of a \^metric ton.^\ \~ton.~\

1.2.1.5 Portland-Pozzolan Cement

The quantity of portland-pozzolan cement to be paid for will be the number of \^metric tons^\ \~tons~\ of portland-pozzolan cement used in the completed and accepted pavements. No measurement or payment will be made for wasted portland-pozzolan cement or for portland-pozzolan cement used for the convenience of the Contractor. The quantity to be paid for will be determined by multiplying the weight in \^kilograms^\ \~pounds~\ of portland-pozzolan cement required by the mixture proportions per cubic \^meter^\ \~yard~\ by the number of cubic \^meter^\ \~yards~\ of the various RCC mixtures placed and measured for payment, then dividing by \^1,000^\ \~2,000~\ and rounding off to the nearest tenth of a \^metric ton.^\ \~ton.~\

1.2.2 Payments

****
NOTE: For fixed-price contracts, inapplicable portions of these paragraphs should be deleted.
****

1.2.2.1 Concrete

The quantity of concrete measured as specified above, will be paid for at the contract unit price when placed in completed and accepted pavements or, where appropriate, at reduced prices adjusted in accordance with paragraph PAYMENT ADJUSTMENT. The unit price shall include the cost of all labor and materials and the use of all equipment and tools required to complete the work, except the cement, pozzolan, or ground slag that is specified for separate payment.

1.2.2.2 Cement

The quantity of cement, determined as specified above, will be paid for at the contract unit price, which includes all costs of handling, hauling, and storage at the site. No adjustment in unit price because of any of the requirements of paragraph PAYMENT ADJUSTMENT will be made in the payment for portland cement.

1.2.2.3 Pozzolan

The quantity of pozzolan determined as specified above, will be paid for at the contract unit price, which includes all costs of delivery, handling, and storage at the site. No adjustment in unit price because of any of the requirements of paragraph PAYMENT ADJUSTMENT will be made in the payment for pozzolan.

1.2.2.4 Ground Granulated Blast Furnace Slag

****
NOTE: If ground iron blast furnace slag is not locally and readily available, remove this paragraph and all further references to the material.
****

The quantity of ground granulated blast furnace slag, determined as specified above, will be paid for at the contract unit price, which includes all costs of handling, hauling, and storage at the site. No adjustment in unit price because of any of the requirements of paragraph PAYMENT ADJUSTMENT will be made in the payment for ground granulated blast furnace slag.

1.2.2.5 Portland-Pozzolan Cement

The quantity of portland-pozzolan cement, determined as specified above, will be paid for at the contract unit price, which includes all costs of handling, hauling, and storage at the site. No adjustment in unit price because of any of the requirements of paragraph PAYMENT ADJUSTMENT will be made in the payment for portland-pozzolan cement.

1.3 GENERAL

The work covered by this section consists of furnishing all plant, material, and equipment, and performing all labor for the manufacturing, transporting, placing, compacting, finishing, jointing, and curing of roller-compacted concrete (RCC) pavement. The work shall be performed within the time frame listed in the SPECIAL CLAUSES of the project specifications.

1.4 SUBMITTALS

****
NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

Indicate submittal classification in the blank space using "GA" when the submittal requires Government approval or "FIO" when the submittal is for information only.
****

Government approval is required for submittals with a "GA" designation; submittals having an "FIO" designation are for information only. The following shall be submitted in accordance with Section \=01300=\ SUBMITTAL DESCRIPTIONS:

SD-01 Data\

Mixing Plant\; *[_____]*\.

Details and data on the RCC mixing plant, prior to plant assembly, including manufacturer's literature on the cementitious material and aggregate feed equipment, water controls, and pug mill mixers, showing that the equipment meets all requirements specified herein.

Hauling Equipment\; *[_____]*\.

A description of the equipment proposed for transporting RCC mixture from the central mixing plant to the placing equipment.

Placing Equipment\; *[_____]*\.

A description of the equipment proposed for the laydown or placing of the RCC mixture, method of control, and manufacturer's literature on the laydown machine (paver), at the time the materials are furnished for the mixture proportioning study. The manufacturer's written instructions on adjustments and operating procedures necessary to assure a tight, smooth surface on the RCC pavement, free of tears and other surface imperfections, including surface pitting shall be included.

Compaction Equipment\; *[_____]*\.

A description of the rollers proposed for use. The description shall include manufacturer's literature and manufacturer's certified results of tests made on the rollers to be used showing the frequency and amplitude of vibration, operating weight, drum dimensions, and pound per lineal inch of the vibratory roller; and the number of wheels, tire pressures, and gross weight of the rubber-tired roller. Documentation certifying that the frequency and amplitude requirements have been tested and met, within 4 months of the commencement of RCC construction.

Nuclear Density Gauge\; *[_____]*\.

A description of the nuclear density gauge apparatus proposed for use. Description shall include manufacturer's literature and the latest manufacturer's calibration results of the nuclear density gauge.

Placing and Spreading\; *[_____]*\.

If concrete is to be placed in or exposed to hot or cold weather conditions, a description of the placing and protection methods proposed, prior to construction of the test section.

Joints\; *[_____]*\. *Curing and protection*\; *[_____]*\.

A detailed plan of the proposed paving pattern showing all planned construction joints and curing water runoff control. The curing media and methods to be used. Unless otherwise directed or approved, placing shall begin along the low side of sloped areas.

SD-07 Schedules\

Paving Operations\; *[_____]*\.

Schedule of paving operations, at least 7 days prior to start of paving unless otherwise specified.

SD-18 Records\

Waybills and Delivery Tickets\; *[_____]*\.

Copies of waybills or delivery tickets for cementitious material, during the progress of the work. Before the final payment is allowed, waybills and certified delivery tickets shall be furnished for all cementitious material used in the construction.

1.5 TEST SECTION

****
NOTE: See Additional Note D.
****

At least 10 days but not more than 60 days prior to construction of the roller compacted concrete pavement, a test section shall be constructed near the job site at the location designated on the contract plans. The Contractor shall notify the Contracting Officer at least 5 days in advance of the date of test section construction. The test section shall consist of not less than two adjacent paving lanes each approximately \^110 meter^\ \~375 feet~\ long and shall be constructed to the thickness and number of lifts designated on the construction plans. The lane width of each paving lane shall be the same as that proposed for use in the project. The test section shall contain at least one fresh longitudinal construction joint, one cold transverse joint, and one longitudinal cold construction joint which has stood overnight before completion. Two separate days shall be used for construction of the test section. The test section will provide the Contractor the opportunity to develop and demonstrate to the satisfaction of the Contracting Officer the proposed techniques of mixing, hauling, placing, compacting, finishing and curing, and the preparation of the construction joints. Additionally, the Contractor shall demonstrate the laydown method and rate, rolling pattern, joint preparation, and rolling method for both fresh and cold construction joints, start-up and finishing procedures, testing methods, and plant operations. Variable amplitudes of the roller shall be used as approved in different areas to identify the optimum amplitude. Rolling pattern of the vibratory and rubber-tired rollers may be varied as approved to determine the best pattern. Variations in mixture proportions other than water shall be made if directed. The test section shall be placed in portions as directed by the Government. The Contractor shall vary the water content, as necessary, to arrive at the appropriate content. The mixing plant shall be operated and calibrated prior to placing the test section. The Contractor shall use the same equipment, materials, and construction techniques on the test section as will be used in all subsequent work. Base course preparation, concrete production, placing, compacting, curing, construction of joints, and all testing shall be in accordance with applicable provisions of this section of the specification. The Contractor shall construct a test section acceptable to the Contracting Officer in all aspects, including surface texture. Failure to construct an acceptable test section will necessitate construction of additional test sections at no additional cost to the Government. [Test sections unacceptable to the Contracting Officer shall be removed at the Contractor's expense.] The Contractor shall provide 12 \^152.4 mm^\ \~6-inch~\ diameter cores and 6 beams \^152.4 mm by 813 mm (6 inches by 32 inches)^\ \~6 inches by 32 inches~\ by full depth (or 12 beams \^152.4 mm by 508 mm (6 inches by 20 inches)^\ \~6 inches by 20 inches~\ by full depth) to the Government from points selected in the test section by the Government 5 days after completion of the test section.

The Contractor shall trim the beams to dimensions directed by the Government before delivery to the Government for inspection and testing.

1.6 MATERIALS, DELIVERY, STORAGE, AND HANDLING

1.6.1 Bulk Cementitious Materials

All cementitious material shall be furnished in bulk. The temperature of the cementitious material, as delivered to storage at the site, shall not exceed \^65 degrees C.^\ \~150 degrees F.~\

1.6.1.1 Transportation

When bulk cementitious material is not unloaded from primary carriers directly into weather-tight hoppers at the batching plant, transportation from the railhead, mill, or intermediate storage to the batching plant shall be accomplished in adequately designed weather-tight trucks, conveyors, or other means that will protect the cementitious material completely from exposure to moisture.

1.6.1.2 Storage

Immediately upon receipt at the site of the work, cementitious materials shall be stored in a dry and properly ventilated structure. All storage facilities shall be subject to approval and shall be such as to permit easy access for inspection and identification. Sufficient cementitious materials shall be in storage to sustain continuous operation of the concrete mixing plant while the pavement is being placed. To prevent cement from becoming unduly aged after delivery, any cement that has been stored at the site for 60 days or more shall be used before using cement of lesser age.

1.6.1.3 Separation of Materials

Separate facilities shall be provided for unloading, transporting, storing, and handling of each type of cementitious material.

1.6.2 Aggregate Materials

1.6.2.1 Storage

Aggregate shall be stored at the site of the mixing plant in such a manner as to avoid breakage, segregation, or contamination by foreign materials. Each size of aggregate from each source shall be stored separately in free-draining stockpiles. Aggregate shall remain in free-draining storage for at least 24 hours immediately prior to use. Sufficient aggregate shall be maintained at the site at all times to permit continuous uninterrupted operation of the mixing plant at the time RCC is being placed.

1.6.2.2 Handling

Aggregate shall be handled in a manner to prevent segregation or degradation. Vehicles used for stockpiling or moving aggregate shall be kept clean of foreign materials. Stockpiles shall be worked in a manner to prevent different sizes of aggregate from being mixed during storage or batching.

1.7 EQUIPMENT

All plant, equipment, tools, and machines used in the work shall be maintained in satisfactory working conditions at all times.

1.7.1 *Mixing Plant*\

1.7.1.1 Location of Mixing Plant

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NOTE: The mixing plant should be on the construction site or as close as possible, but should be no further than 15 minutes haul time from the placing site.

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The mixing plant shall be located [on project site as indicated on plans] [no more than 15 minutes haul time from the placing site].

1.7.1.2 Type of Mixing Plant

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NOTE: Plant capacity should be governed by the laydown pattern or the size of the job to help eliminate or minimize cold joints.

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The mixing plant shall be designed and operated to produce an RCC mixture within the specified tolerances. The plant shall be a stationary-type plant having a twin-shift pug mill mixer and may be either weigh-batch type or continuous type and shall have a minimum capacity of \^[230] [_____] metric tons^\ \~[250] [_____] tons~\ per hour. The plant shall be equipped with positive means for controlling and adjusting the mixing time (amount of mixing), maintaining the time of mixing constant, and maintaining the speed of rotation of the pug mill shafts constant.

1.7.1.3 Cementitious Material Feed Unit

Satisfactory means, incorporating either weighing or volumetric measurements, shall be provided to separately batch or feed the required percentage of each cementitious material in the mixture within tolerances specified. Silos and feeders shall be equipped and operated so that no caking of material or variation in feed will occur, including use of any necessary air pressure or vacuum vents on the silos. Provision shall be made whereby each cementitious material can be readily sampled.

1.7.1.4 Aggregate Bins

Aggregate bins shall be provided for aggregate storage, one for each size group. Each bin shall be of sufficient capacity to supply the mixer continuously operating at full capacity. The bins shall be arranged to ensure separate storage of appropriate fractions of aggregate. Each compartment shall be provided with some means of preventing spilling of material into other bins. Unless the aggregate in the bin is readily visible to operating personnel, each aggregate bin shall be equipped with mechanical or electrical telltales to indicate when the aggregate in the bin is below level to permit accurate proportioning to mixing unit. Each bin shall be constructed or equipped so that a representative sample may be readily and safely obtained from each bin discharge during plant operations. Appropriate means shall be provided for storing, metering, and feeding blending material as defined in paragraph MATERIALS, DELIVERY, STORAGE, AND HANDLING as a separate material when use of blending material is necessary.

1.7.1.5 Water Control Units

Satisfactory means incorporating either weighing, metering, or volumetric measurements shall be provided to batch or feed the required quantity of water in the mixture within tolerances specified. Adjusting controls shall be convenient to and capable of easy and accurate operation by the mixer operator. When the quantity of water is controlled by metering, provision shall be made whereby a fixed quantity of water delivered through the meter

can be readily checked by weight or volume. A water storage tank shall be provided to prevent surge drawdown effect.

1.7.1.6 Batching or Feeding Tolerances

Batching or feeding shall conform to the mixture proportions directed within the following tolerances:

TABLE I

BATCHING OR FEEDING TOLERANCES

Material	Plant*
Each cementitious material	plus or minus 2.0
Water	plus or minus 2.0
Each individual aggregate size group	plus or minus 2.0
Total aggregate	plus or minus 3.0

* For batch-type plants, the variation is in percent by weight from batch weight of each material based on the mixture proportions directed. For continuous feeding and mixing plants, the variation is in percent by weight from the mixture proportions of each material designed to be in a total timed sample obtained from a designated location in the plant.

1.7.1.7 Additional Requirements for Batching and Mixing Plants

a. Plant Scales: Plant scales shall conform to requirements of \-NRMCA CPMB 100-\, with modifications as follows: Plant scales for any weigh box or hopper shall be of either beam or springless-dial type and shall be sensitive to 0.5 percent of maximum load required. Beam-type scales shall have a separate beam for each size aggregate, with a single pointer actuated for each beam and a tare beam for balancing hopper.

b. Weigh Box or Hopper for Aggregates: Weigh box or hopper for aggregates shall conform to requirements of \-NRMCA CPMB 100-\, with modifications as follows: Equipment shall include means for weighing each bin size of aggregate in a weigh box or hopper suspended on scales, ample in size to hold a full batch without running over. The gates on both the bins and the hoppers shall prevent leakage of aggregate when closed. On manually or semi-automatically operated plants, an interlocking device shall be provided to prevent opening more than one gate at a time. The interlocking device is not required on automatic plants designed for simultaneous weighing of all sizes of aggregate while the plant is operating under automatic control.

c. Weigh Hoppers for Cementitious Materials: Weigh hoppers for cementitious materials shall conform to requirements of \-NRMCA CPMB 100-\, with modifications as follows: The weigh hopper shall have sufficient capacity to hold not less than 10 percent in excess of the weight of the cementitious material required for one batch. Portland cement and pozzolan may both be weighed cumulatively in the same hopper on the same scale, provided the portland cement is weighed first, or the portland cement and pozzolan may be weighed in separate hoppers on separate scales. The hopper shall be suspended on dial or beam scales equipped with a pointer so the tare weight of the hopper will be shown for each weighing; net weight of cementitious material shall be measured within 1 percent of the weight required. [Ground granulated blast furnace slag shall be weighed on a separate scale.]

d. Mixer Unit: The mixer for batch method shall be a stationary mixer of the twin pug mill-type capable of producing a uniform mixture within tolerances specified. The mixer shall have a time lock, accurate within 5

seconds, to control operation of the complete mixing cycle by locking the weigh hopper gate after mixer is charged until closing of mixer gate throughout dry- and wet-mixing periods. The dry-mixing period is defined as the interval of time between the opening of the weigh hopper and the application of water. The wet-mixing period is the interval between application of water and the opening of the mixer gate. Control of mixing time shall be flexible and capable of being set at intervals of not more than 5 seconds throughout cycles up to 3 minutes. A mechanical batch counter shall be installed as part of the timing device and shall be designed to preclude register of dry batches or of any material run through during operation of pulling bins.

1.7.1.8 Additional Requirements for Continuous-Mixing Plants

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NOTE: Delete the bracketed statement except for small or low-production jobs.
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a. Aggregate Feed: Each bin shall have the feed rate controlled by a variable speed belt, [or a gate remotely operated from the central control panel,] calibrated to accurately deliver any specified quantity of material within the required tolerance. The feed rate from each bin shall be readily adjustable from the control panel to change aggregate proportions or to compensate for changes in moisture content. The feed rate controls shall automatically maintain the established proportions of aggregate from each bin when the combined aggregate delivery is increased or decreased. The combined aggregate belt feeding the mixer shall be equipped with an approved belt scale. The belt scale shall operate automatic controls, either electronic or mechanical, which will maintain the established proportion of each cementitious material and water as ratios of the total aggregate, with provisions for readily changing the proportions at the control panel. Approved means shall be provided for storing, metering, and feeding blend material as a separate material when use of blending material is necessary.

b. Cementitious Material Control: Approved means shall be provided to separately meter the required amount of each cementitious material in the mix within the tolerance specified. Metering shall be by readily adjustable vane feeders or other approved positive metering devices. Metering and feed shall be so designed and controlled that the cementitious material is uniformly fed into the mixer or into the stream of aggregate on the feeder belt, all with necessary controls to prevent loss of cementitious material as dust or in any other form. Control of the quantity of each cementitious material shall be automatically linked to the aggregate belt scales, as specified herein. Provision shall be made so the amount of each cementitious material delivered can be readily sampled and checked by weight.

c. Mixer Unit: The mixer for the continuous method shall be a stationary mixer of the twin-shaft pug mill type capable of producing a uniform and homogeneous mixture within tolerances specified. Blades shall be adjustable for angular position on shafts and reversible to retard flow of the mixture. The mixer shall bear a manufacturer's plate indicating net volumetric contents of mixer at several heights permanently inscribed on the wall and the rate of feed of aggregate per minute at plant-operating speed.

d. Discharge Hopper: The pug mill shall be equipped with a discharge hopper having a capacity of at least \^1 metric ton.^\ \~1 ton.~\ The hopper shall be equipped with dump gates to assure rapid and complete discharge without segregation.

1.7.2 Pavers

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NOTE: See Additional Note E.
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Pavers shall be heavy-duty, track-equipped machines of the self-propelled type, similar to laydown machines (pavers) used for asphalt concrete or soil-cement construction. The pavers shall be equipped with hoppers, distributing screws, vibrating screen and/or at least one tamping bar, adjustable screeds capable of being operated both manually and automatically, and equalizing devices. The paver shall be of suitable weight and stability to spread and finish the concrete to the indicated thickness, smoothness, and surface texture requirements. The paver shall produce a finished surface conforming to surface smoothness and surface texture requirements specified herein. The paver shall confine edges of lanes to true lines without use of stationary side forms and shall place the concrete to the required thickness, free from segregation. Each side of the paver shall be equipped with interchangeable side forms (shoes) which will form the edge of the pavement lane either vertically or 15 degrees from vertical. Pavers shall be designed to operate forward at variable speeds and in reverse. The pavers shall automatically control both line and grade by means of electronic controls operating from stationary stringlines on both sides of the paver [; slope control devices shall not be used]. However, as appropriate, a short ski riding on an adjacent paved lane may be used in lieu of one of the stringlines. Laser control devices may be used in lieu of a stringline provided the entire process is approved.

1.7.3 Vibratory Rollers

Vibratory rollers shall be self-propelled, double-drum, steel-wheeled vibratory rollers having an average operating weight per drum of at least \^2.7 kg/mm (150 lbs/in)^\ \~150 pounds per lineal inch~\ of drum. The rollers shall transmit a dynamic impact to the surface through the drums by means of revolving weights, eccentric shafts, or other equivalent methods. The roller shall have a vibrating frequency of at least 1,500 cycles per minute. The amplitude shall be between \^0.38 mm and 1.02 mm (0.015 inch and 0.04 inch)^\ \~0.015 inch and 0.040 inch~\ at the operating frequency used. Controls shall permit ready variation of the amplitude at a minimum of two settings over at least 50 percent of the above range. The roller drum shall be between \^1219 and 1676 mm (48 and 66 inches)^\ \~48 and 66 inches~\ in diameter and \^1676 to 2438 mm (66 to 96 inches)^\ \~66 to 96 inches~\ in width. The roller shall be operated at speeds not exceeding \^2.4 km (1.5 miles)^\ \~1.5 miles~\ per hour. Within the range of the operational capability of the equipment, the Contracting Officer may direct or allow variations within the specified range to the frequency, amplitude, and speed of operation which result in the required density and satisfactory surface texture at the fastest production rate. At least one self-propelled vibratory roller, in good operating condition and meeting these requirements, shall be used full time for each paver used full time. The roller shall be equipped with some means of keeping the drums damp during operation. Each drum shall be equipped with an operating scraper and pad. Any rollers which pick up material from the surface of the pavement shall be adjusted, modified, or replaced.

1.7.4 Rubber-Tired Roller

The rubber-tired roller shall have smooth tires, nonoscillating wheels and a tire pressure adjustable between a minimum of \^345 (50)^\ \~50~\ and a maximum of \^620 kPa (90 psi)^\ \~90 pounds per square inch~\ and with a total load between \^1400 kg and 2000 kg^\ \~3,000 and 4,500 pounds~\ per wheel. The roller shall have two axles with at least three wheels per axle, offset so the front and back tires do not track in the same path.

1.7.5 Finish Roller

The smooth-wheeled tandem roller shall weigh \^5 to 9 metric tons.^\ \~5 to 10 tons.~\ The vibratory roller may be used without vibration as a finish roller to remove surface blemishes.

1.7.6 Other Compaction Equipment

Light, walk-behind, or similar sized vibratory rollers and mechanical tampers shall be furnished for use in compacting areas inaccessible to the large rollers.

1.7.7 Straightedge

One \^3.6 meter (12-foot)^\ \~12-foot~\ straightedge shall be furnished for each paving spreader for testing the finished surface. Straightedges shall be made available for Government use upon request. Straightedges shall be constructed of aluminum or other lightweight metal and shall have blades of box or box-girder cross section with flat bottom reinforced to ensure rigidity and accuracy. Straightedges shall have handles to facilitate movement on the pavement.

1.7.8 *Nuclear Density Gauge*\

One operable and properly calibrated nuclear density gauge shall be furnished for each paver. The nuclear density gauge shall be made available for Government use upon request. The nuclear density apparatus shall conform to \-ASTM C 1040-\, Method A, and shall be of a single-probe type.

1.8 ACCESS TO PLANT AND EQUIPMENT

The Contracting Officer shall have access at all times to all parts of the mixing and paving plant for checking adequacy of equipment in use; for inspecting operation of the plant; and for verifying weights, proportions and character of materials.

1.9 SAMPLING AND TESTING INGREDIENT MATERIALS

1.9.1 Sources and Pre-construction Samples for Aggregates

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NOTE: See Additional Note F.
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The sources from which the aggregates are to be obtained shall be designated by the Contractor, and samples representative of the aggregates to be used shall be delivered within 15 days after award of the contract. Only a single source for each fractional size group of aggregates may be designated for testing by the Government. If a sample of material from a proposed source fails to meet specification requirements, the material represented by the sample shall be replaced, and the cost of testing a sample of the replaced material will be deducted from payments due the Contractor. At the same time samples are submitted, a list of at least three portland cement concrete paving projects where each aggregate has been in successful service for at least 5 years shall be submitted. If no service record is available, the aggregates shall conform to the requirements for resistance to freezing and thawing specified herein. If required, freezing and thawing tests will be conducted by the Government. If testing of replaced samples or freezing and thawing testing is required, the Contractor shall be entitled to no time extension because of this. At the option of the Contractor and to expedite construction, mix proportioning samples may be submitted and mix design will begin before the

acceptance testing is completed. However, in this case, if aggregates from the source or sources chosen do not meet specification requirements, additional acceptable samples shall be submitted, the Contractor shall be charged for the additional mix design studies, and the Contractor shall be entitled to no additional payment or time extension because of this.

1.9.2 Samples for Mixture Proportioning Studies

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NOTE: See Additional Note G.
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Representative samples of materials proposed for use in the RCC mixture shall be taken under the supervision of the Contracting Officer in accordance with \-COE CRD-C 100-\ and shall be delivered to (_____) not less than 60 days prior to placing any RCC for the test section. At the same time, test results shall be submitted showing that the samples have been tested and meet the specified requirements. These gradation test results, both for fine and coarse aggregate, will constitute the "Base Gradations" for use as specified in paragraph Aggregate Gradation Tolerances. Representative samples of all other materials shall be submitted accompanied by the manufacturer's test reports indicating compliance with applicable specified requirements. Quantities of materials required shall be as follows:

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Material	Quantity
Coarse aggregate	[_____] kilograms
Fine aggregate	[_____] kilograms
Cement	[_____] kilograms
Pozzolan	[_____] cubic meter
Blending material, if used	[_____] kilograms
Admixtures, if used	[_____] liters
[Ground granulated blast furnace slag, if used	[_____] kilograms]

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Material	Quantity
Coarse aggregate	[_____] pounds
Fine aggregate	[_____] pounds
Cement	[_____] pounds
Pozzolan	[_____] cubic feet
Blending material, if used	[_____] pounds
Admixtures, if used	[_____] quarts
[Ground granulated blast furnace slag, if used	[_____] pounds]

1.9.3 Aggregate Samples

The Contractor shall provide facilities for the ready procurement of representative test samples for Government testing. Samples of aggregates during paving will be obtained at the point of batching. Additional tests and analyses of aggregates at various stages in the processing and handling operations may be made by the Government at the discretion of the Contracting Officer.

1.9.4 Cement

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Note: See Additional Note H.
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Cement will be sampled at the mill or shipping point and at the site of the work and tested by and at the expense of the Government. If tests prove that a cement that has been delivered is unsatisfactory, it shall not be used in the work. When directed by the Contracting Officer, cement that has not been used within 6 months after testing will be retested at the expense of the Contractor, and will be rejected if test results are not

satisfactory. The cost of testing cement excess to the project requirements shall also be at the expense of the Contractor. The charges for testing cement at the expense of the Contractor will be deducted from the payments due the Contractor at a rate of [_____] cents per \^hundred kilograms ^\ \~hundredweight~\ of cement represented by the tests.

1.9.4.1 Prequalified Cement Sources

Cement shall be delivered and used directly from a mill of a producer designated as a qualified source. Samples of cement for check testing will be taken at the project site or the concrete production plant by a representative of the Contracting Officer for testing at the expense of the Government. A list of prequalified cement sources is available from the Commander and Director, U.S. Army Engineer Waterways Experiment Station (ATTN: WESSC), P.O. Box 631, Vicksburg, Mississippi 39180.

1.9.4.2 Other Cement Sources

The sampling, testing, and shipping inspection from the point of sampling when the point of sampling is other than at the site of the work will be made by, or under the supervision of, the Government and at its expense. Cement meeting all other requirements may be accepted before the required 7-day age when the 3-day strength is equal to or greater than the 7-day requirement. In the event of failure, the cement may be resampled and tested at the request of the Contractor and at the Contractor's expense. When the point of sampling is other than at the site of the work, the fill gate or gates of the sampled bin will be sealed and kept sealed until shipment from the bin has been completed. Sealing of the fill gate or gates and of conveyances used in shipment will be done by or under the supervision of the Government. Conveyances will not be accepted at the site of the work unless received with all seals intact. If tested cement is rehandled at transfer points, the extra cost of inspection will be at the Contractor's expense.

1.9.5 Pozzolan

Pozzolan will be sampled at the source and shall be stored in sealed bins pending completion of certain tests. When determined necessary, pozzolan will also be sampled at the site. Initial sampling and testing will be performed by and at the expense of the Government. Release for shipment and approval for use will be based on compliance with 7-day lime-pozzolan strength requirements and other physical, chemical, and uniformity requirements for which tests can be completed by the time the 7-day lime-pozzolan strength test is completed as well as on continuing compliance with the other requirements of the specifications. If the samples from a bin fail, the contents of the bin may be resampled and tested at the Contractor's expense. In this event, pozzolan may be sampled as it is loaded into cars or trucks, provided they are kept at the source until released for shipment. Unsealing and resealing of bins and sealing of shipping conveyances will be done by or under the supervision of the Government. Shipping conveyances will not be accepted at the site of the work unless they are received with all seals intact. If pozzolan is damaged in shipment, handling, or storage, it shall not be used in the work. Pozzolan not used within 6 months after testing will be retested at the expense of the Contractor when directed by the Contracting Officer, and shall be rejected if the test results are not satisfactory. If tested pozzolan is rehandled at transfer points, the extra cost of inspection will be at the Contractor's expense. The cost of testing excess pozzolan will be at the Contractor's expense at a rate of [_____] cents per \^metric ton.^\ \~ton.~\ The amount will be deducted from the payment to the Contractor.

1.9.5.1 Prequalified Pozzolan Sources

Pozzolan shall be delivered and used directly from a producer designated as a qualified source provided a certification is delivered with each lot of pozzolan. Samples of pozzolan for check testing will be taken at the project site or at the concrete producing plant by a representative of the Contracting Officer for testing at the expense of the Government. A list of prequalified pozzolan sources is available from the Commander and Director, U.S. Army Engineer Waterways Experiment Station (ATTN: WESSC), P.O. Box 631, Vicksburg, Mississippi 39180.

1.9.6 Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag will be sampled and tested at the mill or shipping point by and at the expense of the Government to determine if the materials meet the requirements of the specification under which it is furnished. No ground granulated blast furnace slag shall be used until notice of acceptance has been given by the Contracting Officer. Ground granulated blast furnace slag will be subject to check testing from samples obtained at the project site, as scheduled by the Contracting Officer, and such sampling will be by or under the supervision of the Government at its expense. Material not meeting specifications shall not be used in the work.

1.10 ACCEPTABILITY OF WORK

Testing for acceptability of work will be performed by the Government. Mixture proportioning studies will be performed by the Government. Visual examination of the final surface texture will be made by the Government for acceptance. Testing of cementitious materials, aggregates for evaluation of sources, and pavement density, smoothness (straightedge), and thickness will be performed by the Government for acceptance. The Government will sample and test aggregates and concrete during construction to determine compliance with the specifications as specified herein and as otherwise considered appropriate. The Contractor shall provide facilities and labor as may be necessary for procurement of representative test samples. The Contractor shall make his nuclear density gauge and operator available to the Government when requested, at no additional cost to the Government. The Government shall have access at all times to all parts of the paving operation for checking adequacy of equipment in use; inspecting operation of plant; and verifying weights, proportions, and characteristics of materials. Testing performed by the Government shall in no way relieve the Contractor from his testing requirements specified herein.

1.11 PAYMENT ADJUSTMENT

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NOTE: See Additional Note I.

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1.11.1 General

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NOTE: See Additional Note J.

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Where appropriate, adjustment in payment for individual lots of RCC pavement will be made as specified in accordance with the following paragraphs. No such adjustment in payment will be made for cementitious materials. A lot will be that quantity of construction that will be evaluated for compliance with specification requirements. A lot will be equal to [\^400 cu m^\ \~500 cu yd~\] [[_____] \^cu m,^\ \~cu yd,~\] [[_____] [8] hours production], [1 shift production].

1.11.2 Acceptance of Lots

When a lot of material fails to meet the specification requirements, that lot shall be removed and replaced or accepted at a reduced price, as specified herein. The lowest computed percent payment determined for any pavement characteristic (i.e., gradation, density, surface, smoothness, thickness, and surface texture) discussed below will be the actual percent payment for that lot. The actual percent payment is applied to the bid price and to the quantity of RCC pavement placed in the lot to determine actual payment.

1.11.3 Evaluation

In order to evaluate aggregate gradation, and field density, each lot will be divided into four equal sublots. Thickness, surface smoothness, and surface texture determinations will be made on the lot as a whole. For field density determination, one random test will be made on the interior of the paving lane and one random test will be made on each type of lane joint of each sublot. Field density will consist of wet density as determined in accordance with \-ASTM C 1040-\. Field density for each sublot will be compared with the target density for each lot, as described herein. One sample of each size aggregate for determining gradation will be taken for each sublot as the aggregate is discharged to the mixer or from other appropriate location. Gradation of the aggregate will be determined according to \-ASTM C 136-\ and \-ASTM C 117-\. All samples and test locations will be deliberately selected to the truly random, not haphazard, using commonly recognized methods of assuring randomness, employing randomizing tables or computer programs.

1.11.4 Additional Sampling and Testing

The Contracting Officer reserves the right to direct additional samples and tests for any area which appears to deviate from the specification requirements. Testing in these areas will be in addition to the lot testing, and the requirements for these areas will be the same as those for a lot.

1.11.5 Aggregate Gradation

The mean absolute deviation of the four sublot aggregate gradations from the "Base Gradation" for each sieve size of both fine and coarse aggregate will be evaluated and compared with TABLE II. The computed percent payment based on aggregate gradation will be the lowest value determined for either fine or coarse aggregate for any sieve size in TABLE II. All tests for aggregate gradation will be completed and reported within 24 hours after completion of construction of each lot. The computation of mean absolute deviation for one sieve size is illustrated below:

Example -

Assume the following "Base Gradation" and sublot test results for fine aggregate gradation.
\^

Sieve Size	Fine Aggregate "Base Gradation"	Sublot No. 1	Sublot No. 2	Sublot No. 3	Sublot No. 4
	Percent by Weight Passing Sieves				
4.75 mm	100	98	100	97	98
2.36 mm	78	83	80	77	80
1.10 mm	62	65	64	61	64
0.600 mm	45	47	48	44	48
0.300 mm	30	28	31	28	33
0.150 mm	20	18	19	19	17
0.075 mm	8	6	11	12	9

^\\~

Sieve Size	Fine Aggregate "Base Gradation"	Sublot No. 1	Sublot No. 2	Sublot No. 3	Sublot No. 4
	Percent by Weight Passing Sieves				
No. 4	100	98	100	97	98
No. 8	78	83	80	77	80
No. 16	62	65	64	61	64
No. 30	45	47	48	44	48
No. 50	30	28	31	28	33
No. 100	20	18	19	19	17
No. 200	8	6	11	12	9

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Mean Absolute Deviation (for \^0.075 mm^\ \~No. 200 Sieve~\) = ((absolute value of 6 - 8) + (absolute value of 11 - 8) + (absolute value of 12 - 8) + (absolute value of 9 - 8))/4 = (2 + 3 + 4 + 1)/4 = 2.50

The mean absolute deviation for other sieve sizes in the fine aggregate can be determined in a similar way for this example to be:

\^

Sieve Size	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm
Mean Absolute Deviation	1.75	2.50	2.00	2.25	2.00	1.75

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Sieve Size	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100
Mean Absolute Deviation	1.75	2.50	2.00	2.25	2.00	1.75

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The least percent payment based on any sieve size listed in Table II would be 95 percent for the \^0.075 mm^\ \~No. 200~\ sieve. Therefore, for this example, the percent payment based on fine aggregate is 95 percent.

End of Example -

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TABLE II.

PERCENT PAYMENT BASED ON MEAN ABSOLUTE DEVIATION OF FINE AND COARSE AGGREGATE GRADATIONS FROM BASE GRADATION

Percent Payment Based on Mean Absolute Deviation from "Base Gradation"

Sieve Size	0.0-1.0	1.1-2.0	2.1-3.0	3.1-4.0	4.1-50.	5.1-6.0	Above 6.0
19 mm	100	100	100	100	98	95	90
12.5 mm	100	100	100	100	98	95	90
9.5 mm	100	100	100	100	98	95	90
4.75 mm	100	100	100	100	98	95	90
2.36 mm	100	100	100	100	98	95	90
1.18 mm	100	100	100	98	95	90	reject
0.0600 mm	100	100	100	98	95	90	reject
0.300 mm	100	100	100	98	95	90	reject
0.150 mm	100	100	98	95	90	90	reject
0.075 mm	100	100	95	90	reject	reject	reject

^\\~

TABLE II.

PERCENT PAYMENT BASED ON MEAN ABSOLUTE DEVIATION OF FINE AND COARSE AGGREGATE GRADATIONS FROM BASE GRADATION

Percent Payment Based on Mean Absolute Deviation from "Base Gradation"

Sieve Size	0.0-1.0	1.1-2.0	2.1-3.0	3.1-4.0	4.1-50.	5.1-6.0	Above 6.0
3/4 inch	100	100	100	100	98	95	90
1/2 inch	100	100	100	100	98	95	90
3/8 inch	100	100	100	100	98	95	90
No. 4	100	100	100	100	98	95	90
No. 8	100	100	100	100	98	95	90
No. 16	100	100	100	98	95	90	reject
No. 30	100	100	100	98	95	90	reject
No. 50	100	100	100	98	95	90	reject
No. 100	100	100	98	95	90	90	reject
No. 200	100	100	95	90	reject	reject	reject

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1.11.6 Density

1.11.6.1 Field Density

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NOTE: Insert in the blank the depth of the RCC pavement less 50 mm (2 inches).

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To evaluate field density for acceptance, 4 nuclear density gauge tests to determine wet density will be performed at random locations on the interior of the paving lane immediately behind final rolling operations, and four similar tests will be performed at random locations on fresh joints and four at random locations on cold joints, if such exist, for each sublot, and each set will be averaged for the sublot. The locations of the tests on fresh joints will be alternated from side to side of the joint and will be between \^75 and 130 mm^\ \~3 and 5 inches~\ from the joint. For cold joints, it is expected that the primary (originally placed) lane will be placed with one sublot and the secondary lane with another sublot. The

cold joint evaluation for each of these sublots will be based on four density tests made for each sublot being evaluated on that sublot's side of the cold joint. These tests will be between \^75 and 130 mm^\ \~3 and 5 inches~\ from the proposed (sawed) joint line on the originally placed side of the cold joint and between \^75 and 130 mm^\ \~3 and 5 inches~\ from the actual joint on the secondary placement side. All field density tests shall be performed in accordance with \-ASTM C 1040-\, using a single probe nuclear density gauge in the direct transmission mode, with the probe at a depth of [_____] \^mm.^\ \~inches.~\ All field density tests shall be reported separately for each lot within 24 hours after the construction of that lot. All holes left in the pavement as a result of nuclear density testing by both the Government and the Contractor shall be filled by the Contractor with a cement grout, as directed.

1.11.6.2 Target Density

The Government will determine for each lot the laboratory maximum wet density of an RCC sample tested in accordance with \-ASTM D 1557-\ and as described for moisture-density testing in paragraph CONTRACTOR QUALITY CONTROL. If the laboratory maximum wet density determined by the Government and that determined by the Contractor, as required by paragraph CONTRACTOR QUALITY CONTROL, for each lot agree within 2 percent, the densities will be averaged and the result will then become the "target density" for that lot. If the maximum wet densities attained by the Government and Contractor for each lot do not agree within 2 percent, additional moisture-density tests will be performed by the Government until the laboratory maximum wet densities attained from two successive tests agree within 2 percent. In this case, the maximum wet densities of the two successive tests will be averaged to obtain the target density for that lot. This procedure for determining the target density will be repeated for each lot and as necessary whenever the mixture proportions or materials change. Since the "target density" for a lot will not be known until after the beginning of construction of the lot, the "target density" of the previous lot shall be used for quality control until the new "target density" is obtained.

1.11.6.3 Computed Percent Payment for Density

The average field densities for the sublots for lane interior and for each type of joint will in turn be averaged to determine the lot density for the lane interior, for fresh joints, and, if such exist, for cold joints. These lot average field densities will be compared with Table III and used to calculate the computed percent payment based on field density as described below. First, the percent payment deduction for lane interior density, for fresh joint density, and for cold joint density will each be computed by subtracting the percent payment values found in Table III from 100. Then, the weighted percent payment deduction for fresh joint density will be computed by multiplying the percent payment deduction for fresh joint density, as computed above, by the ratio of the total amount of RCC pavement in the fresh joint strip to the total amount of RCC pavement in the entire area of the lot. The area of fresh joint strip will be considered to be \^3 m^\ \~10 feet~\ wide times the length of completed fresh longitudinal construction joint in the lot, but not to exceed the total lot size. Then, the weighted percent payment deduction for cold joint density will be computed by multiplying the percent payment deduction for cold joint density, as computed above, by the ratio of the total amount of RCC pavement in the cold joint strip to the total amount of RCC pavement in the entire area of the lot. The area of cold joint strip will be considered to be \^1.5 m^\ \~5 feet~\ wide times the length of each half of the cold joint (each side of the joint) completed with the lot being evaluated, but not to exceed the lot size. (Although not probable, it could be possible that, for a full lot, both sides of a cold joint can be constructed in the same lot). Next, the percent payment reduction for the lane interior, the weighted percent payment deduction for fresh joint

density, and the weighted percent payment deduction for cold joint density will be compared and the greatest value selected. This selected percent payment deduction will be subtracted from 100 to obtain the computed percent payment based on field density.

TABLE III.

PERCENT PAYMENT FOR DENSITY

Average Lane Interior and Fresh Joint Density (16 Nuclear Density Gauge Readings Each)	Percent Payment	Average Cold Joint Density (16 Nuclear Density Readings)
98.5 and above	100.0	96.5 and above
98.4	99.5	96.4
98.3	99.0	96.3
98.2	98.2	96.2
98.1	97.0	96.1
98.0	95.0	96.0
97.9	86.5	95.9
97.8	81.0	95.8
97.7	72.0	95.7
97.6	65.0	95.6
97.5	58.0	95.5
97.4	52.0	95.4
97.3	47.0	95.3
below 97.3	reject	below 95.3

EXAMPLE OF COMPUTATIONS -

The calculation of computed percent payment based on field density is illustrated below for a typical set of field tests on the lane interior and on the fresh and cold joints in a typical lot.

Assume the following test results for field density made on the lot:

Average lane interior density - 98.0 percent (of target density)
Average fresh joint density - 97.7 percent (of target density)
Average cold joint density - 95.4 percent (of target density)
Total area of lot - \^3000 sq. m^\ \~30,000 sq ft (3,333 sq yd)~\
Length of completed fresh longitudinal construction joint - \^700 m^\ \~2000 ft~\ (Paving lane on each side of joint complete)
Length of cold longitudinal construction joint - \^200 m^\ \~750 ft~\ (Paving lane on one side of joint constructed with this lot)

Step 1: Determine percent payment based on lane interior density and on fresh joint and on cold joint density, using Table III:

Lane interior density of 98.0 percent - 95.0 percent payment
Fresh joint density of 97.7 percent - 72.0 percent payment
Cold joint density of 95.4 percent - 52.0 percent payment

Step 2: Determine percent payment deduction based on lane interior density and on both fresh and cold joint density by subtracting each percent payment from 100:

Lane interior: 100 percent - 95.0 percent = 5.0 percent deduction
Fresh joint: 100 percent - 72.0 percent = 28.0 percent deduction
Cold joint: 100 percent - 52.0 percent = 48.0 percent deduction

Step 3: Determine ratio of fresh joint strip area to lane interior area (total paved area in the lot):

Multiply the length of completed fresh longitudinal construction joint by the specified \^3 m^\ \~10 ft~\ width and divide by the lane interior area (total paved area in the lot):

(\^(700 m x 3 m)/3000 sq m =0.7^\ \~2000 ft. x 10 ft.)/30000 sq ft = 0.6667~\ ratio of fresh joint strip area to lane interior area

Step 4: Determine the weighted percent payment deduction for fresh joint density:

Multiply percent payment deduction for fresh joint density by ratio of fresh joint strip area to lane interior area:

28.0 percent x \^0.7 = 19.6^\ \~0.6667 = 18.7~\ percent weighted percent payment deduction for fresh joint density

Step 5: Determine ratio of cold joint strip area to lane interior area (total paved area in the lot):

Multiply the length of completed cold longitudinal construction joint (one side) by the specified \^1.5 m^\ \~5 ft~\ width and divide by the lane interior area (total paved area in the lot):

(\^(200 m x 1.5 m) 3000 sq m = 0.10^\ \~750 ft x 5 ft)/30000 sq ft = 0.125~\ ratio of cold joint strip area to lane interior area

Step 6: Determine the weighted percent deduction for cold joint density:

Multiply percent payment deduction for cold joint density by ratio of cold joint strip area to lane interior area:

48.0 percent x \^0.10 = 4.8^\ \~0.125 = 6.0~\ percent payment deduction for cold joint density

Step 7: Compare weighted percent payment deduction for fresh joint area, for cold joint area, and for lane interior density, and select the larger:

Percent payment deduction for lane interior density - 5.0 percent
Weighted percent payment deduction for fresh joint density - \^19.6^\ \~18.7~\ percent
Weighted percent payment deduction for cold joint density - \^4.8^\ \~6.0~\ percent
Select the larger = \^19.6^\ \~18.7~\ percent

Step 8: Determine computed percent payment based on field density by subtracting the larger value from Step 7 from 100:

100 - \^19.6^\ \~18.7~\ percent = \^80.4^\ \~81.3~\ percent computed percent payment based on field density.

END OF EXAMPLE -

1.11.7 Surface Smoothness

After the completion of the final rolling of a lot, the compacted surface will be tested by the Government with a \^3.66 m (12-foot)^\ \~12-foot~\ straightedge. Measurements will be made transverse to the paving lane at equal distances along the lane not to exceed \^6 m.^\ \~20 feet.~\ These transverse measurements will be made completely across the paving lane and across the longitudinal construction joints. Measurements will be made longitudinal to the paving lane at separate intervals spaced not more than

\^6 m^\ \~20 feet~\ apart longitudinally as well as across all transverse joints. Longitudinal measurements will be made at third points across the lane. Other areas having visually obvious deviations will also be tested. Location and deviation from straightedge for all measurements will be recorded. When more than 5.0 percent of all measurements within a lot (across the joints and within the lane) exceed the tolerance specified in Table IV, after any reduction of high spots or removal and replacement, the computed percent payment based on surface smoothness will be 95 percent. Regardless of the above, any separate joint or interior area surface deviation which exceeds the tolerance given in Table IV by more than 50 percent shall be removed or corrected to meet the specification requirements of Table IV.

\^

TABLE IV

SURFACE-SMOOTHNESS TOLERANCES

Direction of Pavement Category	Testing	Tolerance, mm (inches)
Tank hardstands, parking areas, open storage areas	Longitudinal	9.5 (3/8)
	Transverse	9.5 (3/8)
Roads and streets	Longitudinal	4.8 (3/16)
	Transverse	6.4 (1/4)
Airfield Pavements:		
Aprons	Longitudinal	6.4 (1/4)
	Transverse	6.4 (1/4)
Taxiways and runways	Longitudinal	3.2 (1/8)
	Transverse	6.4 (1/4)

^\\~

TABLE IV

SURFACE-SMOOTHNESS TOLERANCES

Direction of Pavement Category	Testing	Tolerance, inches
Tank hardstands, parking areas, open storage areas	Longitudinal	3/8
	Transverse	3/8
Roads and streets	Longitudinal	3/16
	Transverse	1/4
Airfield Pavements:		
Aprons	Longitudinal	1/4
	Transverse	1/4
Taxiways and runways	Longitudinal	1/8
	Transverse	1/4

High spots indicated by the testing edge in excess of applicable tolerance shall be marked plainly and removed or reduced by rubbing with a Carborundum brick and water. Rubbing shall be discontinued as soon as contact with the coarse aggregate is made. If high spots cannot be removed in the above manner because of disturbing the coarse aggregate, the high portion of the pavement shall be corrected by an approved surface-grinding machine after the RCC is 14 days old or the defective pavement shall be removed and replaced. When grinding of \^13 mm^\ \~1/2 inch~\ or more

would be required, the pavement shall be removed and replaced. Testing for acceptance or rejection of the finished pavement surface will be performed by the Government. However, at the Contracting Officer's discretion, surface smoothness testing required to be performed by the Contractor in paragraph CONTRACTOR QUALITY CONTROL may be substituted for this Government testing if tests consistently show a satisfactory product.

1.11.8 Thickness

The thickness of the pavement will be determined by the Government on the basis of measurements made on cores drilled by the Contractor from locations outlined in paragraph CONTRACTOR QUALITY CONTROL. Measurements of individual cores will be performed in accordance with \-ASTM C 174-\. The computed percent payment for thickness for the lot will be 100 percent if no core taken for that lot is deficient in thickness by \^6.4 mm (1/4 inch)^\ \~(1/4 inch)~\ or more. When the measurement of any core indicates that the pavement is deficient in thickness by \^6.4 mm (1/4 inch)^\ \~1/4 inch~\ or more, additional cores shall be drilled by the Contractor parallel to the center line of the lane at \^8 m^\ \~25-foot~\ intervals on each side of the deficient core until the cores indicate that the deficiency in thickness is less than \^6.4 mm (1/4 inch).^\ \~1/4 inch.~\ When the deficiencies in thickness for a series of cores are between \^6.4 and 12.7 mm (1/4 and 1/2 inch),^\ \~1/4 1/2 inch,~\ the average thickness will be established from an average of all core thicknesses, considering any core less than \^6.4 mm (1/4 inch)^\ \~1/4 inch~\ deficient as being full depth. Any areas \^12.7 mm^\ \~1/2 inch~\ or more deficient in thickness shall be removed and replaced, recored and included in the measurements before the final calculation of computed percent payment for the lot is made. The computed percent payment for thickness for the lot will then be determined as follows: the proportional part of the total lot area (expressed in percent) for Categories I and II in Table V will be multiplied by their respective percent payment from the table and the two products then added to obtain the computed percent payment for the lot.

Example -

A lot in which 18 percent of the area is deficient in thickness by an average of \^9.5 mm (3.8 inch)^\ \~3.8 inch~\ (Category II) will have a computed percent payment for thickness of:

Category	Proportion of Total Lot Area		Percent Payment From Table IV	Weighted Percent Payment
I	(1.0-0.18) = 0.82	x	100	82.0
II	0.18	x	65	11.7
	Computed Percent Payment for Total Lot =			93.7

End of Example -

The area of pavement for the percent payment calculations shall be considered to be the full paving lane width and midway between cores having thicknesses representing different categories. When any core shows a deficiency in thickness of \^12.7 mm^\ \~1/2 inch~\ or more, the area represented by that core shall be removed and replaced with pavement of the indicated thickness before any payment calculations are made. The area represented by the core shall be bound by the full paving lane width and a transverse line midway between the cores adjacent to the core in question, or the regularly scheduled transverse joint should such a joint fall between the cores. If the Contractor believes that the cores and measurement taken are not sufficient to indicate fairly the actual thickness of the pavement, additional cores shall be taken and will be measured provided the Contractor shall bear the extra cost of drilling the

cores. When surface grinding is required that results in thickness deficiencies, the final surface will be considered in evaluation for thickness.

\^

TABLE V

PERCENT PAYMENT FOR THICKNESS

Deficiency in Thickness Determined by Cores

Percent Payment Category	mm (inches)	(or Action Required)
I	0.0 to 6.3 (0.00 to 0.24)	100
II	6.4 to 12.0 (0.25 to 0.49)	65
III	12.7 or greater (0.50 or greater)	Remove and replace

^\\~

TABLE V

PERCENT PAYMENT FOR THICKNESS

Deficiency in Thickness Determined by Cores

Percent Payment Category	Inches	(or Action Required)
I	0.00 to 0.24	100
II	0.25 to 0.49	65
III	0.50 or greater	Remove and replace

~\

1.11.9 Surface Texture

The surface texture of each lot will be visually examined by a representative of the Contracting Officer immediately after construction to determine compliance with the surface texture requirements in paragraph SURFACE-SMOOTHNESS, SURFACE TEXTURE, AND THICKNESS REQUIREMENTS. The classification of the surface texture of any area of the pavement as acceptable or deficient will be made on the basis of comparison with a selected portion of the test section which has been chosen and marked as having an acceptable surface texture as determined by a representative of the Contracting Officer. The computed percent payment for surface texture requirements for the lot will be determined as follows:

TABLE VI

PERCENT PAYMENT FOR SURFACE TEXTURE

Percent of Lot Area with Deficient Surface Texture	Percent Payment for Action Required
0.0 to 5.0	100
5.1 to 10.0	90
10.1 to 20.0	75
20.1 and above	Remove and replace

Regardless of payment, any area of any size of extremely poor surface texture as determined by a representative of the Contracting Officer shall be removed and replaced full depth with suitable pavement at the expense of the Contractor. No payment calculations will be made until all such defective material is removed and replaced.

1.11.10 Defective Areas

Mixtures that become contaminated or are defective shall be removed. Skin patching of an area that has been rolled will not be permitted. Holes the full thickness of course shall be cut so that the sides are perpendicular and parallel to the jointing pattern and the edges are vertical. Defective areas shall be replaced by sawing full depth of the pavement around the perimeter of the defective area and removing the defective pavement full depth of the course without damaging the adjacent pavement. No such area of defective pavement that is removed and replaced with a new paving mixture shall have a length or width less than \^3 m,^\ \~10 feet,~\ and no adjacent slab or portion of a slab that remains in the pavement abutting the replacement area shall have a length or width less than \^2.5 m^\ \~8 feet~\ when measured from a joint or edge. Prior to the placement of the fresh concrete, the edge of the existing concrete shall form a clean, vertical face to pave against. Conventional concrete or RCC may be used at the Contractor's option to fill the void. The new slab shall conform to all requirements of smoothness, surface texture, density, thickness, and concrete quality, as stated herein. Longitudinal and transverse joints shall be established in the new slab in accordance with the original plans and shall be sealed, if required for the adjacent slab. The replaced pavement will be paid for in the same manner as new pavement, but no payment will be made for the defective pavement or for the removal of the defective pavement.

PART 2 PRODUCTS

2.1 CEMENTITIOUS MATERIALS

2.1.1 Portland Cement

****
NOTE: See Additional Note K.
****

Shall conform to \-ASTM C 150-\, Type [_____], [low alkali] [, including the false set requirement].

2.1.2 Pozzolan

****
NOTE: See Additional Note L.
****

Shall conform to the requirements of \-ASTM C 618-\, Class F [or C,] including the supplemental optional uniformity requirements, as contained in Table IV [, and the supplemental optional requirements for limit on available alkalies, as contained in Table II, and for limit on reactivity with cement alkalies, as contained in Table IV].

2.1.3 Portland-Pozzolan Cement

****
NOTE: The optional requirement for mortar expansion should be specified when the portland-pozzolan cement will be used with alkali-reactive aggregate.
****

Shall conform to the requirements of \-ASTM C 595-\, Type IP or Type I(PM) [, including the optional requirement for mortar expansion contained in Table II].

2.1.4 Ground Granulated Blast Furnace Slag

****
NOTE: If ground granulated blast furnace slag is not locally and readily available, remove this paragraph and all other references to the material in this specification.
****

Shall conform to the requirements of \-ASTM C 989-\.

2.2 WATER

Water shall conform to the requirements of \-COE CRD-C 400-\ and shall be clean, fresh, and free from injurious amounts of oil, acid, salt, alkali, organic matter, and other substances deleterious to the hardening of concrete, and shall be subject to approval.

2.3 CURING MATERIALS

Burlap shall conform to \-FS CCC-C-467-\

2.4 AGGREGATES

The Contractor shall furnish separately both fine and coarse aggregates that meet requirements of these specifications. The coarse aggregate shall consist of at least 90 percent by weight of aggregate retained on the \^4.75 mm^\ \~No. 4~\ sieve, and the fine aggregate shall have at least 90 percent by weight of aggregate passing the \^4.75^\ \~No. 4~\ sieve. Gradation of the fine and coarse aggregates shall meet the requirements of the following:

2.4.1 Coarse Aggregate

****
NOTE: See Additional Note M.
****

Coarse aggregate shall consist of crushed or uncrushed gravel, crushed stone, air cooled blast furnace slag, or a combination thereof. [Crushed gravel shall contain not less than 60 percent by weight of crushed uncrushed particles size having at least one freshly fractured face, in each sieve.]

2.4.1.1 Quality

****
NOTE: See Additional Note N.
****

Coarse aggregates shall consist of clean, hard, uncoated particles meeting the requirements of \-ASTM C 33-\ and as otherwise specified. [Dust and other coatings shall be removed from the coarse aggregate by washing.]

2.4.1.2 Particle Shape

Particles of the coarse aggregate shall be generally spherical or cubical in shape. The quantity of flat and elongated particles in any size group shall not exceed 20 percent by weight as determined by \-ASTM D 4791-\.

2.4.1.3 Deleterious Substances

****
NOTE: See Additional Note O.
****

The total of all deleterious substances shall not exceed 3.0 percent by weight of the coarse aggregate. The percentage of material finer than \^0.075 mm^\ \~No. 200~\ sieve shall not be included in this total. The limit for material finer than \^0.075 mm^\ \~No. 200~\ sieve will be increased to 1.5 percent for crushed aggregates consisting of crusher dust that is essentially free from clay or shale. The amount of deleterious substances in each size group of coarse aggregate shall not exceed the limits shown below.

\^

TABLE VII

LIMITS OF DELETERIOUS SUBSTANCES FOR COARSE AGGREGATE

Substance	Percentage by Weight
Clay lumps and friable particles (\-ASTM C 142-\)	2.0
Material finer than 0.075 mm sieve (\-ASTM C 117-\)	1.0
Lightweight particles (\-ASTM C 123-\, using a separation medium with a specific gravity of 2.0)	1.0
Other soft particles (\-COE CRD-C 130-\)	2.0

^\\~

TABLE VII

LIMITS OF DELETERIOUS SUBSTANCES FOR COARSE AGGREGATE

Percentage Substance	by Weight
Clay lumps and friable particles (\-ASTM C 142-\)	2.0
Material finer than No. 200 sieve (\-ASTM C 117-\)	1.0
Lightweight particles (\-ASTM C 123-\, using a separation medium with a specific gravity of 2.0)	1.0
Other soft particles (\-COE CRD-C 130-\)	2.0

~\

2.4.1.4 Resistance to Freezing and Thawing

Coarse aggregate not having a demonstrable service record as required by paragraph Sources and Pre-Construction Samples for Aggregates shall have a durability factor of 50 or more when subjected to freezing and thawing in accordance with \-COE CRD-C 114-\ using conventional concrete test specimens.

2.4.1.5 Resistance to Abrasion

Coarse aggregate shall not show more than 40 percent loss when subjected to the Los Angeles abrasion test in accordance with \-ASTM C 131-\.

2.4.2 Fine Aggregate

Fine aggregate shall consist of natural sand, manufactured sand, or a combination of the two meeting the requirements of \-ASTM C 33-\. Where necessary to meet grading requirements, a fine blending material may also be used.

2.4.2.1 Particle Shape

Particles of the fine aggregate shall be generally spherical or cubical in shape.

2.4.2.2 Deleterious Substances

The amount of deleterious substances in the fine aggregate shall not exceed the following limits:

LIMITS OF DELETERIOUS SUBSTANCES FOR FINE AGGREGATE

Substance	Percentage by Weight
Clay lumps and friable particles (\-ASTM C 142-\)	1.0
Lightweight particles (\-ASTM C 123-\, using a separation medium with a specific gravity of 2.0)	0.5

2.4.2.3 Resistance to Freezing and Thawing

Fine aggregate not having a demonstrable service record as required by paragraph Sources and Pre-Construction Samples for Aggregates shall have a durability factor of 50 or more when subjected to freezing and thawing in accordance with \-COE CRD-C 114-\ using conventional concrete test specimens.

2.4.2.4 Blending Material

To meet the specified gradation, additional fines (minus \^0.150 mm^\ \~No.

100~\ and \^0.075 mm^\ \~No. 200~\ sieve size material), if necessary, shall be provided by adding to the aggregates a fine blending sand or pozzolan (fly ash). If pozzolan is used, it shall be the same material as furnished for cementitious material as required by paragraph CEMENTITIOUS MATERIALS. Pozzolan, if used for this purpose, shall be batched or fed together with pozzolan used as cementitious material and shall be furnished at the Contractor's expense. Blending sand, if used, shall be a clean, hard, siliceous material meeting all quality requirements specified herein for fine aggregate and shall be furnished to the mixer as a separate material.

2.4.3 Aggregate Gradation

Aggregates shall consist of at least two size groups, coarse aggregate and fine aggregate (with blending material, if necessary, as previously described), each of which shall have a gradation such that the two or more materials can be combined in proportions which will produce a combined gradation within the limits given in the following table. Each size group

of aggregate and blending material shall be batched separately or otherwise fed separately to the mixer. After receiving the samples submitted by the Contractor for mix proportioning studies, the Contracting Officer will develop from them a combined gradation curve and the proportions of each size of aggregate to be used in the mixture. The combined gradation curve may or may not fall within the limits listed below, as considered appropriate by the Government. Proportions may be adjusted by the Government during progress of the work to improve characteristics of the mixture.

\^

Combined Aggregate Gradation for Samples to be Submitted for Mix Design Studies

Sieve Size	Cumulative Percent by Weight Passing
25 mm	100
19 mm	83-100
12.5 mm	72-93
9.5 mm	66-85
4.75 mm	51-69
2.36 mm	38-56
1.18 mm	28-46
0.600 mm	18-36
0.300 mm	11-27
0.150 mm	6-18
0.075 mm	2-8

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Combined Aggregate Gradation for Samples to be Submitted for Mix Design Studies

Sieve Size	Cumulative Percent by Weight Passing
1 inch	100
3/4 inch	83-100
1/2 inch	72-93
3/8 inch	66-85
No. 4	51-69
No. 8	38-56
No. 16	28-46
No. 30	18-36
No. 50	11-27
No. 100	6-18
No. 200	2-8

~\

2.4.4 Aggregate Gradation Tolerances

Gradation of each size group of aggregate, including any necessary blending material delivered to the mixer shall match the "Base Gradation" for each size of aggregate within the following tolerances. The "Base Gradations" are the gradations of each size of aggregate as furnished for mix design studies, as specified in paragraph Samples for Mixture Proportioning Studies. Proportions of each size of aggregate entering the mixer shall conform to the proportions furnished by the Government and as adjusted by the Government, within the tolerances specified in paragraph: Batching or Feeding Tolerances.

\^

Allowable Tolerances for Gradation of Each Size of Aggregate

Sieves	Tolerance, plus or minus Percentage points
12.5 mm, 9.5 mm	5
2.36 mm, 1.18 mm, 0.600 mm	4
25 mm, 19 mm, 4.75 mm, 0.300 mm	3
0.150 mm, 0.075 mm	2

^\\-

Allowable Tolerances for Gradation of Each Size of Aggregate

Sieves	Tolerance, plus or minus Percentage points
1/2 inch, 3/8 inch,	5
No. 8, No. 16, No. 30	4
1 inch, 3/4 inch, No. 50, No. 4	3
No. 100, No. 200	2

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2.5 ADMIXTURES

Retarding admixture, if used, shall conform to \-ASTM C 494-\, Type B or D.

2.6 MIXTURE PROPORTIONING

2.6.1 Composition

Concrete shall be composed of cementitious material, water, and fine and coarse aggregates, including any necessary fine blending material. The cementitious materials shall be portland cement in combination with pozzolan or, at the Contractor's option, cementitious material may be [portland-pozzolan cement] [portland cement in combination with ground granulated blast furnace slag]. A retarding admixture may be used, if approved. Other admixtures shall not be used unless demonstrated by the Contractor to be beneficial, approved in writing, and used in the mixture proportioning studies.

2.6.2 Control

The initial proportions determined from the mixture proportioning studies will be furnished to the Contractor by the Contracting Officer. The mixture proportions other than water shall be changed by the Contractor during construction as directed by the Contracting Officer's representative. The water content shall be varied by the Contractor, as necessary, to provide a consistency that is most conducive to effective placing and compaction and that will assure that the required densities in the pavement and required surface texture are attained. The aggregate weights shall be changed by the Contractor, as necessary, to compensate for varying aggregate moisture.

2.6.3 Cementitious Material Content

****
NOTE: See Additional Note P.
****

The total cementitious material content will range from an approximate minimum of [_____] to an approximate maximum of [_____] \^kilograms per

cubic meter,^\ \-pounds per cubic yard,-\ expressed as equivalent portland cement content (by absolute volume). Unless portland-pozzolan cement is furnished, a pozzolan shall be furnished and will be proportioned to be between [_____] and [_____] percent by absolute volume of the total cementitious material. Any pozzolan used in addition to that required as a cementitious material, to act as a fine blending material to provide necessary fines in the aggregate, shall be furnished at no cost to the Government. Portland-pozzolan cement, if furnished, will be proportioned within the range specified above for total cementitious material content. [If ground granulated blast furnace slag is used the proportions will vary between 25 and 50 percent by absolute volume of the cementitious material, depending on the temperature during placing. No pozzolan or portland-pozzolan cement will be used if ground granulated blast furnace slag is used.]

2.6.4 Aggregate Content

The proportions of aggregate shall be as determined by the mixture proportioning studies or as determined appropriate by the Contracting Officer during construction.

2.6.5 Flexural Strength

The Government will be responsible for initial mixture proportions and for varying mixture proportions during construction as necessary to achieve the desired flexural strength.

2.6.6 Water Content

The initial or start-up water content will be provided to the Contractor by the Government with initial mixture proportions. After start-up, the total water content of the mix shall be controlled by the Contractor as necessary to meet all requirements stated herein. The water content shall be varied at frequent intervals by the Contractor, as necessary and as considered appropriate, because of placing and compacting operations and shall in general be based on the action of the vibratory roller on the freshly placed concrete and on the field-density test results attained in the pavement and on the surface texture being produced.

PART 3 EXECUTION

3.1 SURFACE-SMOOTHNESS, SURFACE TEXTURE, AND THICKNESS REQUIREMENTS

3.1.1 Surface Smoothness

Pavements shall be smooth and true to grade and cross section (except for grade changes) as determined in accordance with paragraph PAYMENT ADJUSTMENT. Deficiencies in the smoothness shall be treated as described in paragraph PAYMENT ADJUSTMENT.

3.1.2 Final Surface Texture

The final surface texture of the pavement, after all rolling and curing, shall be smooth and uniform over the whole area of the pavement and shall be totally free of any surface pitting, voids or indentations, pockmarks, surface tears, check cracking, segregation or rock pockets, pumped areas, aggregate drag marks, areas loosened by construction operations, and areas where fines have been washed away during the curing process. Deficiencies shall be treated as described in paragraph PAYMENT ADJUSTMENT.

3.1.3 Thickness

Pavements shall be constructed to the thicknesses indicated on the plans. Thickness shall be determined and deficiencies treated as described in paragraph PAYMENT ADJUSTMENT.

3.2 GRADE CONTROL

Lines and grades shown on contract drawings for each pavement category of the contract shall be established and maintained by means of line and grade stakes. Finished pavement gradelines and elevations shown shall be established and controlled at the site of work by the Contractor in accordance with bench mark elevations furnished by the Government. The surface of the underlying material shall be finished to the necessary grade such that when the required thickness of RCC is placed, the pavement surface will meet the indicated grade. Finished and completed RCC pavement shall conform to the lines, grades, cross section, and dimensions indicated.

3.3 CONDITIONING OF UNDERLYING MATERIAL (BASE COURSE AND SUBBASE)

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NOTE: Designer will include the title of the applicable specification section used for base course or subgrade, and delete inappropriate sections.

****

Previously constructed underlying material shall be conditioned as specified in Section [\=02232=\ SELECT-MATERIAL SUBBASE COURSE] [\=02233=\ GRADED-CRUSHED-AGGREGATE BASE COURSE] [\=02234=\ SUBBASE COURSE] [\=02235=\ LIMEROCK BASE COURSE] [\=02238=\ BITUMINOUS-STABILIZED BASE COURSE, SUBBASE, OR SUBGRADE] [\=02239=\ PORTLAND CEMENT-STABILIZED BASE OR SUBBASE COURSE] [\=02240=\ LIME-STABILIZED BASE COURSE, SUBBASE, OR SUBGRADE] [\=02241=\ STABILIZED-AGGREGATE BASE COURSE] [\=02242=\ BITUMINOUS BASE COURSE]. In all cases prior to placing concrete, deficiencies in the underlying material shall be corrected, and the surface shall be cleaned and moistened, as directed. The surface of the underlying material will be inspected by the Contracting Officer.

3.4 BATCHING, MIXING, AND TRANSPORTING

The plant shall be operated to produce a uniform and homogeneous mixture. The proportions shall be as furnished to the Contractor, except for water content, which is the responsibility of the Contractor. All materials used in the mixture shall be batched or fed separately except that fly ash used as aggregate fines shall be batched or fed with fly ash used as cementitious material.

3.4.1 Mixing

The aggregates and cementitious materials shall be conveyed to the mixer in proportions, as required. Water shall be controlled at the amount selected by the Contractor. In batch mixing, aggregates and cementitious materials shall be charged into the mixer and dry-mixed at least 15 seconds. Water shall be added, and mixing shall be continued as required to obtain a homogeneous mixture. When a continuous mixer is employed, mixing time shall be not less than 35 seconds and as much longer as may be required to obtain a homogeneous mixture. The paddles of the pug mill shall be adjusted, as necessary, to provide the required mixing time and to provide a thorough scrubbing action to the mixture. Shaft speed of the pug mill shall be maintained at the speed recommended by the manufacturer. Concrete shall not extend above the tips of the paddles of the pug mill mixer when

paddles are in vertical position. Mixer and mixer paddle surfaces shall be kept free of hardened concrete and other contamination. Mixer paddles worn down more than 10 percent from new paddles of the same type and manufacture shall be replaced.

3.4.2 Transporting

Concrete shall be hauled from the mixer to the placing site in dump trucks equipped with protective covers. The trucks shall dump directly into the hopper of the paver or into an approved secondary material distribution system which deposits material into the paver hopper. Dumping RCC directly on the underlying course will not be permitted except at start-up of a lane. Deliveries shall be scheduled so that concrete will be spread and rolled within the time limit specified in paragraph COMPACTION and spreading and rolling of all mixture prepared for 1 day's run can be completed during daylight unless adequate artificial lighting is provided. Loads that have crusts of partially hardened material or have become wet by rain will be rejected. Hauling over freshly placed concrete will not be permitted, except as approved by the Contracting Officer on the lower compacted lift of multilift-pavements.

3.5 *PLACING AND SPREADING*\

3.5.1 General Requirements for Use of Paver

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NOTE: If the total pavement thickness is greater than 250 mm (10 inches), use the first statement in brackets regarding lift thickness; otherwise, the second statement should be used.
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Except as specified below for certain extremely small odd-shaped isolated areas, all concrete shall be placed and spread with the paver. The level of concrete in the paver hopper shall not be allowed to approach empty between loads, and concrete shall be maintained above the auger shaft during paving. The paver shall be adjusted and the speed regulated so that segregation is prevented and the surface will meet all requirements of paragraph SURFACE-SMOOTHNESS, SURFACE TEXTURE, AND THICKNESS REQUIREMENTS, and of such depth that, when compacted, the surface will conform with cross section, grade, and contour indicated. [No layer shall be in excess of \^250 mm^\ \~10 inches~\ or less than \^100 mm^\ \~4 inches~\ in compacted thickness.] [The entire depth of pavement shall be placed as one layer.] Each edge of each lane shall be constructed with a vertical or a 15 degrees from vertical configuration, as directed. Mixture shall be placed in consecutive adjacent strips having a minimum width of \^3 m^\ \~10 feet~\ and a maximum width of \^6 m,^\ \~20 feet,~\ except when edge lanes require strips less than \^3 m^\ \~10 feet~\ to complete an area. If more than 60 minutes shall elapse between placement in adjacent lanes the construction joint shall be considered a "cold joint" and treatment as specified herein for cold joints shall be provided. Not more than 60 minutes shall elapse between placement of lifts on multilift construction. During extremely hot weather, both of these limits will be decreased by the Contracting Officer as specified in paragraph Placing During Hot Weather or as otherwise considered appropriate. Each strip placed before a succeeding strip shall be of such length that, where practical, the succeeding strip can be placed without the use of a cold joint. Pavers shall be used in sufficient numbers and operated in staggered formation to assist in achieving the above requirement and to produce multilane construction in one construction operation to minimize cold construction joints. Otherwise, the joint shall be constructed as a cold joint. In multilift construction, a separate paver shall be required for placement of each lift of pavement. The length of a strip that is to be followed by another strip shall be approved and shall be decreased or increased as required by air temperatures, wind, and

other climatic conditions existing at the time of placement. Longitudinal joints and edges shall be constructed to true line markings. Lines parallel to the center line of an area to be paved shall be established, and stringlines shall be placed coinciding with established lines for the spreading machine to follow. In multilift construction, a separate paver shall be required for placement of each lift of pavement. Placing of mixture shall be as nearly continuous as possible, with an absolute minimum of stops and starts; absolute minimum of stops and starts; speed of placing shall be controlled, to permit proper rolling. The timing of placement shall be controlled so that all RCC mixture shall be placed and rolled within the time limit specified in paragraph COMPACTION. Placing shall be discontinued during rain except for light mists which do not cause intermixing of cement and water slurry on the surface. Placing shall be done in a pattern so that curing water from previous placements will not pose a runoff problem on the fresh surface or base course. The pavers shall at all times be controlled by automatic electronic controls operating from two stringlines or from a stringline on one side and a ski on the adjacent previously paved lane, or from a laser system, all as specified in paragraph Pavers.

3.5.2 Placing Adjacent Lanes

Fresh Longitudinal Construction Joints between separate lanes of concrete pavement shall be completed within the time limitations in the paragraph PLACING AND SPREADING. Other longitudinal joints shall be treated as "cold joints." Joints shall be made to assure continuous bond between old and new sections of pavement. Extra passes of the vibratory roller and other compaction and hand finishing shall be used as necessary to assure specified full depth compaction and surface finish.

3.5.3 Special Requirements for Placing Lanes Succeeding Initial Lanes

For longitudinal construction joints the screed of the paver shall overlap the previously placed lane \^25 to 50 mm^\ \~1 to 2 inches~\ and shall be sufficiently high so that compaction will produce a smooth, dense joint, without offset. The concrete placed on the edge of the previously placed lane by the paver shall be carefully pushed back by hand by using a lute to the edge of the lane being placed, so none will remain on the surface of the previously placed lane. If necessary, when the quantity of concrete on the edge of the previously placed lane plus uncompacted material in the lane being placed exceeds that required to produce a smooth, dense joint, the excess concrete shall be removed by approved methods and wasted.

3.5.4 Handwork

Any paving operations that require significant handwork, other than as specified above, shall be stopped and the problems corrected before restarting. Broadcasting or fanning of concrete mixture over areas being compacted will not be permitted. When segregation occurs in the concrete during placement, the spreading operation shall be suspended until the cause is determined and corrected. Segregated coarse aggregate shall be removed from the surface prior to compaction. Irregularities in alignment of the pavement left by the mechanical spreader shall be corrected by hand trimming directly behind the spreader before rolling. Distortion of pavement during edge trimming will not be permitted.

3.5.5 Placing Odd-Shaped Areas

In isolated instances involving very small, odd-shaped areas where use of machine spreading is impractical, concrete shall be spread by hand. Spreading shall be in a manner to prevent segregation. Mixture shall be spread uniformly with shovels in a loose layer of thickness that, when

compacted, will conform to density, grade, thickness, and surface texture requirements.

3.5.6 Placing During Cold Weather

Placement shall be discontinued when the air temperature reaches \^5 degrees C^\ \~40 degrees F~\ and is falling and shall not be resumed until the air temperature reaches \^2 degrees C^\ \~35 degrees F~\ and is rising.

No RCC shall be placed on any surface containing frost or frozen material. Provision shall be made to protect the concrete from freezing during the specified curing period. Mixing water and/or aggregates shall be heated, as necessary, to produce concrete having a temperature between \^10 degrees C^\ \~50 degrees F~\ and \^30 degrees C^\ \~85 degrees F~\ as placed.

Methods and equipment for heating shall be as approved. The aggregates shall be free of ice, snow, and frozen lumps before entering the mixer. Covering and other means shall be provided for maintaining the RCC at a temperature of at least \^10 degrees C^\ \~50 degrees F~\ for not less than 72 hours after placing and at a temperature above freezing for the remainder of the curing period. Concrete damaged by freezing shall be removed and replaced as directed.

3.5.7 Placing During Hot Weather

During periods of hot weather when the maximum daily air temperature is likely to exceed \^30 degrees C,^\ \~85 degrees F,~\ the following precautions shall be taken. The maximum period between placing succeeding lifts or lanes shall be 45 minutes. The underlying material shall be sprinkled with water immediately before placing the concrete. The concrete shall be placed at the coolest temperature practicable, and in no case shall the temperature of the concrete when placed exceed \^32 degrees C.^\ \~90 degrees F.~\ The aggregates and/or mixing water shall be cooled as necessary. The finished surfaces of the newly laid pavement shall be kept damp by applying a waterfog or mist, not streams of water, with approved spraying equipment until the pavement is covered by the curing medium. When heat or wind is determined excessive by the Contracting Officer, the Contractor shall immediately take such additional measures as necessary to protect the concrete surface. Such measures shall consist of wind screens, more effective fog sprays, and similar measures commencing immediately behind the paver. If these measures are not effective, paving operations shall be immediately stopped until satisfactory placement conditions exist.

3.6 COMPACTION

Compaction shall be accomplished by self-propelled, vibratory, steel-wheeled rollers and rubber-tired rollers. Rolling shall begin within 10 minutes of spreading and, except for fresh joints, rolling shall be completed within 45 minutes of start of mixing, except during hot or dry weather conditions. In hot or dry weather, rolling shall begin within 5 minutes of spreading and, except for joints, rolling shall be completed within 30 minutes of start of mixing. Delays in rolling freshly laid mixture will not be permitted. Initial rolling shall consist of a minimum of four complete vibratory passes of the vibratory roller. In no case shall this requirement for vibratory rolling be relaxed. Initial static passes may be necessary before the vibratory rolling to "set" the pavement surface before vibratory compaction is started. A round trip over the same material shall count as two complete passes (i.e., from point A to point B and return to point A by the same route are two complete passes). Rollers shall not be operated in the vibratory mode when not moving. The frequency and amplitude of vibration shall be varied, as needed or directed, within the range specified in paragraph EQUIPMENT. After initial vibratory rolling, preliminary tests and examination of density, crown, grade, smoothness, and surface texture shall be made by the Contractor under the supervision of the Contracting Officer. Before rolling is continued,

deficiencies shall be corrected so that the finished surface will conform to requirements for grade, surface texture, and smoothness specified herein. Further smoothness checks shall be as directed by the Contracting Officer. Rolling shall be continued with the vibratory roller in vibratory mode, if necessary, until wet field density of not less than 98.5 percent of the "Target Density," maximum wet density per \-ASTM D 1557-\, is attained in the lane interior and at fresh joints or until 96.5 percent of the "Target Density," maximum wet density per \-ASTM D 1557-\, at a cold joint is attained. Nuclear density testing shall be performed in accordance with paragraph CONTRACTOR QUALITY CONTROL. Once at 4 least passes of the vibratory roller operating in the vibratory mode have been made and the specified density is attained, rolling with the steel wheeled vibratory roller shall stop. Surfaces of roller drums and wheels shall be kept clean at all times. Vibratory rolling beyond that specified above will not be permitted. All additional rolling beyond 4 vibratory passes required to produce the specified field density shall be at the Contractor's expense. As soon as rolling with the vibratory roller is complete, the pavement surface shall receive at least two complete passes of the rubber-tired roller with tire pressure and loading per wheel at the midpoint of the range previously specified, unless otherwise directed. These passes shall be followed by 2 complete passes of the finish roller.

3.6.1 Operation of Rollers and Tampers

Speed of rollers shall be slow enough at all times to avoid displacement of the concrete but in no case more than \^2.5 km/hr.^\ \~1.5 mph.~\ Displacement of concrete resulting from reversing direction of roller or from any other cause shall be immediately corrected. Alternate passes of roller shall be varied slightly in length and shall overlap sufficiently to provide full coverage over the surface. Additional rollers shall be furnished if pavement density specified is not attained and/or if paving operations are getting ahead of rolling. In no case shall the Contractor allow a situation to occur where paving operations have to be altered to accommodate a lack of rollers. Places inaccessible to large vibratory rollers shall be thoroughly compacted with walk-behind rollers and hand-tampers to the required density, using multiple thin lifts, as necessary. Additional field density tests shall be made for those areas by the Contractor and may also be made by the Government.

3.6.2 Rolling Pattern

Rolling shall commence at the outer edge of the lane, followed by the other edge, and then the center. On subsequent adjacent lanes, rolling shall begin at the outer edge. The first pass along each edge shall extend to within approximately \^450 mm^\ \~18 inches~\ of the edge except as otherwise approved or directed. If there will be a subsequent lane placed along an edge and the joint will be constructed as a "fresh" joint, the roller shall go no closer to the outer edge until the subsequent lane Is placed. If there will be a subsequent lane and the joint will be treated as a "cold" construction joint, or if the edge will be the final edge of the pavement, the outer \^450 mm^\ \~18 inches~\ shall be rolled after rolling of the center of the lane. If the edge abuts a previously placed strip, either as a "fresh" joint or as a "cold" joint, the uncompacted joint area shall be rolled after the center of the lane. This joint area shall be given additional passes of the vibratory roller and rubber-tired roller, as necessary, to produce the specified compaction in the joint area. Approved hand-finishing operations shall be used as necessary to produce a tight surface at the joint, meeting the specified surface tolerances in Table IV. The rolling pattern shall be used consistently throughout production.

3.7 *JOINTS*\

Joints shall conform to the details indicated and shall be perpendicular to the finished grade of the pavement. Joints shall be straight and continuous from edge to edge of the pavement. Construction joints shall be made to ensure continuity in smoothness and grade between old and new sections of pavement, as specified hereinafter. All joints shall have the same texture, full-depth density, and smoothness as specified for other sections of pavement. Regardless of age, contact surfaces of previously constructed strips that have become coated with dust, sand, or other objectionable material shall be cleaned by brushing or cut back with approved power saw, as directed.

3.7.1 Longitudinal Construction Joints

Any construction joints in which the edge of the initial strip has exceeded the time requirements given in paragraph PLACING AND SPREADING shall be considered "cold joints" and shall be trimmed by sawing the edge of the hardened concrete with a power concrete saw, not earlier than 12 hours age.

The sawcut shall be at least \^150 mm^\ \~6 inches~\ from the original edge, and more if necessary to produce an acceptable joint. The sawcut shall be full depth of the pavement and shall produce a face within 15 degrees of vertical, free of all loose or uncompacted material. The outer portion shall be removed carefully to prevent any damage to the sawed face.

If damage occurs, the edge shall be resawed. If necessary, additional rolling shall be used to assure that full depth density and surface texture is attained.

3.7.2 Transverse Construction Joints

When a transverse construction joint is required, the roller shall pass over the end of the freshly placed concrete. In these cases, the previously placed concrete shall be cut with a power concrete saw to full depth of the lift, as specified above, and the excess material removed. In continuing placement of the strip, the paver shall be positioned on the transverse joint so that sufficient fresh concrete will be spread to obtain a joint, after rolling, which will conform to required full-depth density and smoothness specified. When necessary, the fresh mixture shall be hand finished at the joints. Additional rolling shall be used to assure that specified full-depth density and surface finish is attained.

3.7.3 Joints in Multilift Construction

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NOTE: Delete this paragraph if only one course construction is to be used in the project. Delete bracketed statement if all lift joints are to receive bedding mortar.

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The top layer shall be placed so that longitudinal joints in that layer will coincide with joints in the lower layers of the pavement. Transverse joints in the top layer shall coincide with transverse joints in the lower layers of the pavement. All portions of the lower layer that are to be covered by the upper layer shall be covered with a bedding mortar layer \^6 to 10 mm^\ \~1/4 inch to 3/8 inch~\ thick immediately before placing the upper layer [if the time between successive layers exceeds 30 minutes].

Bedding mortar shall be a mixture of cement, fine aggregate and water of the proportions directed and shall be spread evenly over the lower layer.

3.7.4 Slip Joints

Slip joints shall be constructed between roller-compacted and conventional concrete where no expansion joint is required and as shown on the plans. The edge of the initial placement, either RCC or PCC, shall be coated with a bituminous product a minimum of \^3 mm^\ \~1/8 inch~\ thick prior to placing the next material. If RCC is placed prior to conventional concrete, the RCC shall be sawcut full depth at the joint line and excess RCC removed.

3.7.5 Sawing of Contraction Joints

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NOTE: See Additional Note Q.
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Transverse contraction joints shall be sawed at \^12 m.^\ \~40 ft.~\ spacing or as otherwise indicated. Joint sawing shall be accomplished where indicated by using a \^3 mm (1/8 inch)^\ \~1/8-inch~\ blade to the depth indicated. The time of sawing shall vary depending on existing and anticipated weather conditions and shall be such as to prevent uncontrolled cracking of the pavement. Sawing of the joints shall commence as soon as the concrete has hardened sufficiently to permit sawing the concrete without chipping, spalling, or tearing. After expiration of the curing period, the upper portion of the groove shall be widened by sawing to the width and depth indicated to form a reservoir for the joint sealer. The sawed faces of joints will be inspected for undercutting or washing of the concrete due to the early sawing, and sawing shall be delayed if undercutting is sufficiently deep to cause structural weakness or excessive roughness in the joint. The sawing operation shall be carried on, as required, during both day and night regardless of weather conditions. The joints shall be sawed at the required spacing consecutively in the sequence of the concrete placement. A chalkline or other suitable guide shall be used to mark the alignment of the joint. The saw cut shall not vary more than \^13 mm^\ \~1/2 inch~\ from the true joint alignment from edge to edge of the pavement area, and shall have no abrupt offsets. Before sawing a joint, the concrete shall be examined closely for cracks, and the joint shall not be sawed if a crack has occurred within \^3 m^\ \~10 feet~\ from the planned joint location. Sawing shall be discontinued when a crack develops ahead of the saw cut. Immediately after the joint is sawed, the saw cut and adjacent concrete surface shall be thoroughly flushed with water until all waste from sawing is removed from the joint. Water-curing systems shall be discontinued only in small areas to facilitate sawing. The sawing equipment shall be adequate in the number of units and the power to complete the sawing at the required rate. An ample supply of saw blades shall be available on the job before concrete placement is started, and at least one standby sawing unit in good working order shall be available at the jobsite at all times during the sawing operation. [Longitudinal construction joints between lanes shall be sawed to form a reservoir for joint sealant in the same manner as specified above.]

3.7.6 Routing Cracks

Thirty to 45 days after placement of concrete, all cracks which have been opened to \^3 mm^\ \~1/8 inch~\ or more shall be routed to the dimensions shown. Routing shall be done in a manner to minimize spalling, using a vertical spindle type rotary router so mounted on a rigid chassis that the spindle will caster.

3.7.7 Sealing Joints and Cracks

Joints and cracks shall be sealed immediately following routing of cracks or sawing of joint reservoir or as soon thereafter as weather conditions

permit. Joints and cracks shall be sealed as specified in Section \=02592=\ FIELD MOLDED SEALANTS FOR SEALING JOINTS IN RIGID PAVEMENTS.

3.8 *CURING AND PROTECTION*\

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NOTE: See Additional Note R.
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Commencing immediately after rolling is complete in each area of each lane, the surface of the pavement shall be kept continuously wet by means of a water spray truck and/or wet burlap. After the initial 12 hours of curing, the pavement shall be cured for 7 days by a sprinkler system and/or wet burlap covering.

3.8.1 Water Spray

3.8.1.1 Trucks

Water trucks shall be used, as necessary, to keep pavement surfaces wet at all times until the sprinkler system and/or wet burlap covering is implemented. The water truck shall be supplemented, as necessary, by mists from hand-held hoses. The truck operator shall be positioned so he is capable of seeing the spray at all times. The spray shall be capable of easy direction, either by attachment to the front of the truck so it can be directed by steering the truck or by other approved means. All spray nozzles both on the trucks and the hand held hoses shall be of a type that produces a true fog spray without any concentrated streams of water. The mist shall not be applied in a channelized or pressurized manner that in any way erodes the surface of the pavement. It shall also be applied at a rate which does not cause ponding at the surface. Trucks shall not be allowed to drop visible oil or other contaminants on the surface. If trucks must leave the pavement, the tires shall be washed free of dirt or other foreign material before returning to the pavement. Water truck wheel loads shall not exceed \^2000 kg^\ \~4,500 pounds~\ and shall be such that no cracking or other damage to the pavement is caused.

3.8.1.2 Sprinkler Systems

An approved sprinkler system consisting of pipe lines and rotating or other approved type of sprinklers shall be used. Sprinklers shall deliver a fine mist of water and shall not cause any erosion to the surface of the concrete. The sprinkler system shall be in place within 12 hours of placing each area of RCC, cover all portions of the pavement area, and keep the pavement wet at all times.

3.8.2 Burlap

Burlap covers shall consist of two or more layers of burlap having a combined weight of \^4746 gm per sq m (14 oz per sq yd)^\ \~14 ounces or more per square yard~\ in a dry condition. Burlap shall be either new or shall have been used only for curing concrete. Burlap strips shall have a length after shrinkage of at least 1 foot greater than necessary to cover the entire width and edges of the pavement. Mats shall overlap each other at least \^150 mm.^\ \~6 inches.~\ Mats shall be thoroughly wetted before placing and shall be kept continuously wet and in intimate contact with the surface and edges of the pavement area for the entire curing period.

3.8.3 Cure Water Runoff Control

Any water applied to the surface of the RCC pavement or burlap during curing that is in excess of the amount needed to keep the surface of the RCC continuously wet shall be controlled from running onto the base course

and causing ponding on the base course or saturation of the base or subbase material.

3.8.4 PROTECTION OF PAVEMENT

After final rolling of the pavement, no vehicular traffic, except for pneumatic-tired water spray trucks or other curing equipment having wheel loads not exceeding \^2000 kg,^\ \-4,500 pounds,-\ shall be permitted on the RCC pavement until the end of the curing period. No traffic or equipment shall be allowed on the surface that will cause any damage to the surface. Plastic sheeting meeting the requirements of \-ASTM C 171-\ shall be provided and kept readily available to cover pavement less than 12 hours old if rainfall occurs.

3.9 DISPOSAL OF UNSATISFACTORY MATERIALS

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NOTE: Use the appropriate disposal area or procedure for the locale.

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Any concrete that is removed for the required correction of defective areas, waste material, and debris shall be disposed of [as directed] [in disposal area indicated].

3.10 CONTRACTOR QUALITY CONTROL

3.10.1 General

The following tests and inspections shall be the responsibility of the Contractor and shall be performed by an approved commercial testing laboratory or by approved Contractor personnel:

a. Calibration of mixing plant.

b. Sampling, gradation, and quality testing of aggregates during construction.

c. Aggregate moisture tests.

d. Moisture-density testing.

e. Field density and moisture testing.

f. Surface-smoothness determinations (straightedge testing).

g. Coring to provide specimens for the Government to determine pavement thickness, including filling the core holes as directed.

h. Inspection during placing.

Based upon the results of these tests, the Contractor shall take the action and submit reports as required below, and any additional tests to ensure that the requirements of these specifications are met. Any test results requested by the Government for review shall be provided to the Government immediately, and all results of every test by the Contractor shall be furnished to the Government on a daily basis, not later than the day after the test or inspection is made. All core drilling and all surface-smoothness determinations shall be performed by skilled personnel experienced in such work. Verification tests of materials, RCC, and pavements, if made by the Government, shall in no way relieve the Contractor from the testing requirements specified herein.

3.10.2 Inspection Details and Frequency of Testing

The following number of tests will be the minimum acceptable for each type of operation:

3.10.2.1 Calibration of Mixing Plant

a. Batch-Mixing Plants: Accuracy of the batching equipment shall be checked for each type of cementitious material and aggregate at the beginning of operations and at least once for every 10 shifts in the presence of the Contracting Officer's representative. Such checks shall also be made whenever there are variations in properties of the fresh concrete which could be the result of batching errors. Standard test weights accurate to plus or minus 0.1 percent shall be provided for checking plant scales.

b. Continuous-Mixing Plants: Accuracy of proportioning of the continuous-mixing plant shall be checked for each cementitious material every day at the beginning of operations and for each aggregate at the beginning of construction and after every 10 shifts. The accuracy of proportioning shall be checked by simultaneously securing timed samples of the cementitious materials and the combined aggregate as they are fed to the mixer and weighing each as appropriate.

c. Mixing Time: Mixing time of the pug mill shall be checked at the direction of the Government. Unless otherwise required, determination of mixing time shall be by weight method using the following formula:

Mixing time in seconds = pug mill dead capacity in \^kg^\ \~pounds~\/ pug mill output in \^kg^\ \~pounds~\ per second

3.10.2.2 Sampling, Sieve Analysis, and Quality of Aggregate

a. Sampling: Sampling and testing of aggregates during construction shall be performed by an approved commercial testing laboratory using appropriate Corps of Engineers and ASTM test methods.

b. Sieve Analysis: A sieve analysis on the fine and coarse aggregates as delivered to the mixer shall be made by the Contractor at the specified frequency. Before starting work, at least one sample of aggregate shall be tested in accordance with \-ASTM C 136-\ and \-ASTM C 117-\. The aggregate shall not be used unless results verify that the aggregate complies with the specified gradation and tolerances. After the initial test, a minimum of one analysis shall be performed for each \^400 cubic meters^\ \~ 500 cubic yard~\ or portion thereof of RCC material placed each shift. When deficiencies are found, the rate of testing shall be increased as directed.

When two consecutive tests show the aggregate to be deficient in grading, the mixing operation shall be stopped until acceptable material is furnished for delivery to the mixer.

c. Aggregate Quality Tests: During construction, the Contractor shall test for quality both sizes of the aggregates used for RCC construction. Tests shall consist of Los Angeles abrasion, magnesium sulfate soundness, clay lumps and friable particles, lightweight pieces, other soft particles, and specific gravity determination. Tests for quality shall be performed at least once for each \^4,000 cubic meters^\ \~5,000 cubic yards~\ of pavement and otherwise when there may be a visual change in the aggregate. [Tests for deleterious materials in airfield pavements shall be made for every 5000 cubic yards of pavement and more often as directed if problems exist.]

3.10.2.3 Aggregate Moisture Tests

At the beginning of the day and as otherwise directed by the Contracting Officer, the Contractor shall perform moisture content tests on the coarse and fine aggregates in accordance with \-ASTM C 566-\.

3.10.2.4 Moisture-Density Testing

Moisture-density tests shall be conducted on the concrete in accordance with the procedure contained in \-ASTM D 1557-\ (Method C or D, whichever is appropriate) in which the maximum wet density of the concrete is determined. A moisture-density test shall be conducted prior to the start of the first day's construction on mixture proportions provided by the Government and thereafter at the start of each subsequent lot of construction. Additional tests shall be conducted whenever the mixture proportions or materials change. During construction, samples for moisture-density tests shall be taken from the discharge of the plant mixer. The samples shall be compacted in accordance with \-ASTM D 1557-\ within 2 hours of the beginning of mixing for the lot. Density results shall be reported and used on the basis of wet density, although dry density shall be reported for information only. The target density for each lot shall be as specified in paragraph PAYMENT ADJUSTMENT.

3.10.2.5 Field Density Testing

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NOTE: See Additional Note S.
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a. Calibration Block for the Nuclear Density Gauge: A calibration block shall be fabricated by the Contractor with concrete materials and proportions representative of those to be used during construction. The block shall be used each day before paving begins to calibrate the full-depth readings of the nuclear density gauges used by the Contractor and the Government. The block shall be fabricated before the test section construction begins. The block size shall be \^450 mm by 450 mm^\ \~18 inches by 18 inches~\ by the maximum thickness of one lift, plus \^25 mm.^\ \~1 inch.~\ The block shall be compacted to between 98 and 100 percent of the maximum wet density, which will be determined by the Government in accordance with \-ASTM D 1557-\. The moisture content of the concrete used to fabricate the block may be increased just enough to facilitate compaction of the mixture, as long as the proportions of the dry materials remain constant and the required density is achieved. The block shall be measured and weighed to determine the actual density (unit weight) and shall be used to check the calibration of the nuclear density gauge. After drilling a hole in the block to accommodate the nuclear density gauge probe, three full depth nuclear density gauge tests shall be performed in the direct transmission mode and the results averaged. This average nuclear density gauge reading shall be compared with the measured unit weight of the block and the difference used as a correction factor for all readings taken that day. All measuring and weighing of the test block and all calibration checking of the density gauge shall be performed in the presence of a representative of the Contracting Officer. Calibration checks of the density gauge shall be made at the beginning of pavement construction every day. The calibration block shall be available for use by the Government as needed.

b. Field Density and Moisture Testing: Field density tests shall be performed on the pavement in accordance with \-ASTM C 1040-\ as soon as possible, but within 30 minutes, after the completion of vibratory rolling.

Only wet density shall be used for evaluation. The test shall be performed using a single probe nuclear density gauge operating in the direct

transmission mode so density of the full depth of the pavement can be measured. Each test shall include readings at depths of [_____], [_____] and [_____] \^mm;^\ \~inches;~\ however, only the deepest reading shall be used to evaluate the density. Both wet and dry densities shall be reported, and all individual readings shall be reported. The moisture content shall be determined in accordance with \-ASTM D 3017-\ at the same depths. The wet field density shall also be reported as a percentage of the "Target Density," maximum laboratory wet density as determined for that lot in accordance with \-ASTM D 1557-\, as specified in paragraph PAYMENT ADJUSTMENT. All holes left in the concrete as a result of nuclear density testing shall be filled with a cement grout.

c. Frequency of Field Density and moisture Testing: At least one field density test shall be performed for each \^30 m^\ \~100 feet~ of paving lane of each layer of RCC and at least one for each \^30 m^\ \~100 linear feet~\ of longitudinal and traverse construction joint. Additional tests shall be made as directed, particularly during start-up and when problems with attaining required density occur.

3.10.2.6 Surface-Smoothness Determination (Straightedge Testing)

Immediately after rolling is complete in each area, but in no case later than 1 hour after the concrete has been placed, the surface of the pavement shall be tested with an approved \^3.66 m (12 foot)^\ \~12-foot~\ straightedge or other approved device that will reveal all surface irregularities varying from the testing edge exceeding tolerances specified in Table IV. The entire area of the pavement involved shall be tested in both a longitudinal and a transverse direction on parallel lines \^3 m^\ \~10 feet~\ or less apart. The straightedge shall be held in contact with the surface and moved ahead one-half the length of the straightedge for each successive measurement. Straightedge lines shall be carried continuously across joints. The testing shall be performed by the Contractor in the presence of a representative of the Contracting Officer. This testing shall be in addition to Government testing for surface smoothness specified in paragraph PAYMENT ADJUSTMENT.

3.10.2.7 Coring Specimens to Determine Pavement Thickness

Cores shall be drilled by the Contractor from points in the pavement within 7 days after placement of the pavement. A minimum of one core per sublot will be taken from locations selected in a random fashion by the Contracting Officer. Cores shall be \^150 mm^\ \~6-inch~\ diameter.

Additional cores shall be drilled by the Contractor if required as specified in paragraph PAYMENT ADJUSTMENT. Refilling of core holes shall be performed with portland cement mortar, using materials and procedures directed. Cores shall become the property of the Government and may be tested for strength determination or other properties as considered appropriate.

3.10.2.8 Inspection During Placing

The placing foremen shall supervise all placing operations and shall be responsible for measuring and recording concrete temperatures, ambient temperature, weather conditions, time of placement, yardage placed, and method and location of placement.

a. Cold-Weather Placing: At least once during each shift, an inspection shall be made of all areas subject to cold-weather protection. Deficiencies shall be noted. During removal of protection, the concrete and ambient temperature shall be measured at least hourly.

b. Hot-Weather Placing and Initial Curing at All Times: When the maximum daily air is likely to exceed \^30 degrees C,^\ \~85 degrees F,~\

the Contractor shall take and record the temperature of the concrete mixture at 30-minute intervals during hot-weather placement. The surface of the base course shall be inspected to assure that it is sprinkled with water immediately before the concrete is placed and any deficiencies noted.

Regardless of ambient temperature, the finished concrete shall be inspected to assure that it is kept damp until the curing medium is applied and any deficiencies noted and immediately brought to the attention of the Contracting Officer's representative. Immediate steps shall be taken to correct any deficiencies.

c. Curing Operation: The curing operation shall be inspected to assure that the surface of the pavement is kept very moist (or wet) continuously until the end of the curing period.

3.10.3 Action Required

3.10.3.1 Mixing Plant

Whenever it is found that either the weighing or the batching accuracy does not comply with specification requirements, the plant shall be shut down until necessary adjustments or repairs have been made. Discrepancies in recording shall be corrected immediately.

3.10.3.2 Aggregate Grading and Quality

a. Grading: When the amount passing any sieve is outside the specification limits or tolerances, the aggregate shall be immediately resampled and retested. If the second sample fails on the same sieve, that fact shall be reported to the Contracting Officer and immediate steps shall be taken to correct the grading.

b. Quality: When the aggregate fails to meet the specification limits for Los Angeles abrasion, magnesium sulfate soundness, clay lumps and friable particles, lightweight pieces, other soft particles, and specific gravity, the Contracting Officer shall be notified immediately and approved corrective action shall be taken.

3.10.3.3 Field Density and Moisture Testing

If any nuclear density gauge reading is below 97.8 percent for interior or fresh joint or below 95.8 percent for a cold joint, another test shall be performed within a \^1.5 to 2.5 m^\ \-5-to 8-foot-\ radius of the previous testing location. If this adjacent reading is also below the density requirements, the Contracting Officer shall be notified immediately, and additional vibratory roller passes shall be made across the full lane width between the last testing location that produced an acceptable reading and the paver. If additional vibratory roller passes cause the density to decrease or cause the surface texture and appearance to deteriorate in the opinion of the Contracting Officer, the paving operation shall be discontinued until appropriate adjustments are made to the moisture content of the mixture, to the operation of the paver, to rolling procedures, or other operations to assure that the specified density and surface requirements can be achieved.

3.10.3.4 Surface Smoothness

When straightedge testing indicates any areas where readings exceed the tolerances listed in Table IV, the Contracting Officer shall be notified immediately, and the paving operation shall be immediately modified to eliminate this.

3.10.3.5 Inspection

a. Temperature Protection: The Contracting Officer shall be notified whenever the concrete temperature during the period of protection or protection removal fails to comply with the specifications, and immediate steps shall be taken to correct the situation. Regardless of the ambient temperature, when the temperature of the concrete mixture exceeds \^32 degrees C,^\ \~90 degrees F,~\ mixing and placing shall be stopped and the Contracting Officer notified.

b. Curing Operation: The Contracting Officer shall be notified when any pavement surface is allowed to dry before the end of the curing period, and immediate steps shall be taken to correct the situation.

c. Reports: All results of tests conducted at the project site shall be reported daily and shall be delivered to a designated representative of the Contracting Officer. During periods of cold weather protection, reports of pertinent temperatures shall be made daily. These requirements do not relieve the Contractor of the obligation to report certain failures immediately as required in preceding paragraphs. Such reports of failure and the action taken shall be confirmed in writing in the routine reports. The Contracting Officer has the right to examine all Contractor quality control records at any time.

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ADDITIONAL NOTES

NOTE A: For additional information on the use of all CEGS, see CEGS-01000 CEGS GENERAL NOTES.

NOTE B: In preparing contract specifications for RCC pavement construction, the Contracting Officer will use Appendix D of TM 5-822-7/AFM 88-6, Chapter 8, for further guidance.

NOTE C: The Designer must carefully correlate and edit the bid items, measurement and payment paragraphs, and all the technical paragraphs so use of portland cement, pozzolan, portland-pozzolan cement, and ground granulated blast furnace slag will be well coordinated. Do not permit use of ground slag with pozzolan or portland-pozzolan cement. Either use no separate pozzolan or use only a greatly reduced amount if portland-pozzolan cement is used.

NOTE D: For noncritical pavement areas, the test section may be included into the actual pavement area. For critical areas, the test section should be constructed in a separate area near the jobsite, with similar conditions and pavement section to the actual construction site.

The specification requirement of building the test section 10 days before the main construction begins may be lengthened or shortened in the project specifications depending on the confidence of the designer in the ability to obtain the design flexural strength in the test section.

If the test section will be included into the actual pavement area, the specs should be modified to provide that the test section shall be removed if it is unacceptable.

NOTE E: Slope control devices can be used in roadway paving to establish a crown, but a stringline should be used along the center line for the first lane. Insert the bracketed wording for all pavement except roadway or other two-lane pavements.

NOTE F: If samples came from a source without a proven performance record, at least 90 days will be needed to perform the required freezing and thawing tests. Further guidance on this testing period, including the option to deliver aggregates within 15 days after award of contract, should be obtained from the Government testing laboratory.

Satisfactory service record for an aggregate will be determined based on the aggregate's ability to resist degradation under traffic and/or climatic conditions similar to that expected during its use. If performance data indicate that an aggregate is susceptible to one or more of the above mentioned problems, that source of aggregate shall be rejected.

NOTE G: Generally, 700 kg (1,500 pounds) of coarse aggregate, 700 kg (1,500 pounds) of fine aggregate, 200 kg (400 pounds) of cement, and 60 liters (2 cubic feet) of pozzolan will be sufficient to accomplish mix proportioning. Normally the earliest time to start paving the test section will be 60 days after all materials are delivered to the laboratory for mix design, provided the materials meet all specification requirements, although this can be shortened somewhat if absolutely necessary. Designer should contact the laboratory regarding time scheduling and material quantities, particularly if an accelerated schedule becomes necessary.

NOTE H: For projects with less than 4,000 cubic meters (5,000 cubic yards) of RCC, delete this paragraph and the following subparagraph concerning pozzolan and ground slag and require submission of certified results of mill tests for cement, pozzolan, and ground granulated blast furnace slag.

Contact the Government testing laboratory for guidance on cost of retesting.

NOTE I: If Payment Adjustment is not used, the entire specification will have to be very carefully edited. In addition to other items, there will have to be inserted, at some appropriate location, the acceptance criteria to be used for surface smoothness and thickness, which are presently covered only in paragraph Payment Adjustment.

Criteria requires that the Government perform Acceptance Testing. However, if it is determined that this is impossible and deletion is approved, the testing required for acceptance must be specified to be the Contractor's responsibility and

the entire specification carefully edited accordingly.

If it is absolutely necessary to cut down a minor amount on the amount of acceptance testing, the acceptance testing for aggregate gradation during paving operations can be deleted. In this case the entire PAYMENT ADJUSTMENT paragraph must be very carefully edited.

Do not under any conditions reduce the requirements for density, surface smoothness, surface texture, or thickness or the testing required for those items. Do not under any conditions reduce the requirements for daily calibration of the nuclear density meter with the cast block of RCC.

Do not under any conditions reduce the requirements for use of vibratory rollers operating in the vibratory mode or for use of electronic controls and stringlines or lasers.

If it is determined impossible to have Government mix designs, it will be necessary to specify mix design studies to be performed by the Contractor. In this case it will be necessary to specify the flexural strength that must be attained at the appropriate age, the required percent of overdesign, the test methods to be used and the number of test specimens, and the number of trial mixes required (with varying w/c ratios and cementitious material contents to bracket the final value). Do not insert in the specifications a compressive strength to be used for acceptance during construction. Criteria contained herein for required field density is adequate to control strength if mix design studies have been performed properly.

NOTE J: The lot size can be specified on the basis of time (i.e., 4 hours, 1 shift, etc.) or amount of production (i.e., 500 cu m (yd), 1000 cu m (yd), etc.) If the lot size is based on the amount of production, it normally should be selected to be approximately equal to the amount of RCC expected to be produced in 1 shift of operation. The lot size should not exceed 1500 cu m (2000 cu yd) of RCC. When a lump-sum contract is used, the lot size becomes the total job; thus, the percent payment is applied to the contract price. The following paragraphs will be edited accordingly.

NOTE K: The option of Type I or Type II portland cement should normally be specified, but only type II portland cement should be required when moderate resistance to sulfate attack is needed. Low alkali cements should be required when alkali reactive aggregates are used in the concrete. The false set requirement should be added if a history of false set exists for the area.

NOTE L: The supplemental requirements for limit on alkalies and limit on reactivity in brackets should be specified any time low alkali cement is specified or if class C pozzolan is permitted. Class C

pozzolan should not be used if there is potential for sulfate attack.

NOTE M: Crushing the gravel tends to improve quality and bond characteristics and generally results in higher flexural strength of concrete and a more stable mixture under compaction. When mixture proportioning studies or local experience indicates that low flexural strength will be attained by using an uncrushed gravel, the possibility of attaining higher strength by crushing the gravel will be investigated. When desirable to limit coarse aggregate to crushed materials, modify the paragraph by deleting uncrushed gravel and adding the sentence in brackets.

NOTE N: If history of aggregate sources in the project area indicates lower concrete strengths are caused if dust and other coatings are not washed from the aggregate, then the option in brackets for washing aggregate should be considered if economically justified.

NOTE O: For airfield pavements, paragraph 2.4.1.3 shall be deleted and the following paragraph shall be used. Edit to retain only the one applicable column. (See TM 5-822-7 for guidance.)

"2.4.1.3 Deleterious Substances

The amount of deleterious materials in coarse aggregate shall not exceed the following limits:

LIMITS OF DELETERIOUS MATERIALS FOR COARSE AGGREGATE
FOR AIRFIELD PAVEMENTS
(Percentage by Weight)

Materials	Areas with Major Popouts Severe Weather	Areas with Major Popouts Moderate Weather	Areas with Minor Popouts Severe Weather	Areas with Minor Popouts Moderate Weather
Clay lumps (\-ASTM C 142-\)	0.2	0.2	2.0	2.0
Shale(a) (\-ASTM C 295-\)	0.1	0.2	1.0	1.0
Material finer than 0.075 mm (No. 200) sieve(b) (\-ASTM C 117-\)	0.5	0.5	1.0	1.0
Lightweight particles(c) (\-ASTM C 123-\)	0.2	0.2	0.5	0.5

Clay ironstone(d) (\-ASTM C 295-\)	0.1	0.5	1.0	1.0
Chert and cherty stone less than 2.40 specific gravity SSD)(e) (\-ASTM C 295-\)	0.1	0.5	1.0	5.0
Claystone, Mudstone, and siltstone(f) (\-ASTM C 295-\)	0.1	0.1	1.0	1.0
Shaly and argillaceous limestone(g) (\-ASTM C 295-\)	0.2	0.2	1.0	1.0
Other soft particles \-COE CRD-C 130-\)	1.0	1.0	1.0	2.0
Total of all deleterious substances exclusive of Material finer than 0.075 mm (No. 200 sieve)	1.0	2.0	3.0	5.0

a. Shale is defined as a fine-grained thinly laminated or fissile sedimentary rock. It is commonly composed of clay or silt or both. It has been indurated by compaction or by cementation, but not so much as to have become slate.

b. Limit for material finer than 0.075 mm (No. 200) sieve will be increased to 1.5 percent for crushed aggregates if the fine material consists of crusher dust that is essentially free from clay or shale.

c. The separation medium shall have a specific gravity of 2.0. This limit does not apply to coarse aggregate manufactured from blast-furnace slag unless contamination is evident.

d. Clay ironstone is defined as an impure variety of iron carbonate, iron oxide, hydrous iron oxide, or combinations thereof, commonly mixed with clay, silt, or sand. It commonly occurs as dull, earthy particles, homogeneous concretionary masses, or hard-shell particles with soft interiors. Other names commonly used for clay ironstone are "chocolate bars" and limonite concretions.

e. Chert is defined as a rock composed of quartz, chalcedony or opal, or any mixture of these forms of silica. It is variable in color. The texture is so fine that the individual mineral grains are too small to be distinguished by the unaided eye. Its hardness is such that it scratches glass but is not scratched by a knife blade. It may contain impurities such as clay, carbonates, iron oxides, and other minerals. Other names commonly applied to varieties of chert are: flint, jasper, agate, onyx, hornstone, procellanite, novaculite, sard, carnelian, plasma, bloodstone, touchstone,

chrysoprase, heliotrope, and petrified wood. Cherty stone is defined as any type of rock (generally limestone) that contains chert as lenses and nodules, or irregular masses partially or completely replacing the original stone.

f. Claystone mudstone, or siltstone, is defined as a massive fine-grained sedimentary rock that consists predominantly of clay or silt without laminations or fissility. It may be indurated either by compaction or by cementation.

g. Shaly limestone is defined as limestone in which shale occurs as one or more thin beds or laminae. These laminae may be regular or very irregular and may be spaced from a few inches down to minute fractions of an inch. Argillaceous limestone is defined as a limestone in which clay minerals occur disseminated in the stone in the amount of 10 to 50 percent by weight of the rock; when these make up from 50 to 90 percent, the rock is known as calcareous (or dolomitic) shale (or claystone, mudstone, or siltstone).

The size of the sample shall be at least 20 kg (50 pounds) for the coarse aggregate and 5 kg (10 pounds) for the fine aggregate. The Contractor shall provide facilities for the ready procurement of representative test samples. Samples shall be taken and tested by and at the expense of the Contractor, using appropriate Corps of Engineers and ASTM test methods. Additional tests and analyses of aggregates at various stages in the processing and handling operations may be made by the Government at the discretion of the Contracting Officer. The testing procedure on each sample of coarse aggregate for compliance with limits on deleterious materials shall be as follows:

Step 1: Test at least 5 kg (10 pounds) of the sample for material finer than the 0.075 mm (No. 200) sieve.

Step 2: Wash off material finer than 0.075 mm (No. 200) sieve from the remainder of the sample and recombine with material retained on the 0.075 (No. 200) sieve from step 1.

Step 3: Test full sample for clay lumps and friable particles and remove.

Step 4: Test full sample for light-weight particles and remove, and then for chert and/or cherty stone with SSD specific gravity of less than 2.40 and remove.

Step 5: Test full sample for clay-ironstone, shale, claystone, mudstone, siltstone, shaly and/or argillaceous limestone, and remove.

Step 6: Test at least 5 kg (10 pounds) of the remaining sample for other soft particles.

Determination of deleterious materials listed in Step 5 shall be performed by an individual specifically trained in petrographic identification. The individual selected to perform the identification of these deleterious materials shall be subject to approval and at least 10 days before any individual is proposed to commence this type of work, the Contractor shall submit a written resume of the individual's training and experience for approval by the Government. The Contractor will not be entitled to any extension of time or additional payment due to any delays caused by the testing, evaluation or personnel requirements specified herein."

NOTE P: An appropriate range for most cases is 250 (minimum to 350 (maximum) kg per cubic meters (400 (minimum) to 600 (maximum) pounds per cubic yard) of cementitious material, and 25 to 40 percent pozzolan by absolute volume of cementitious material. Add sentence in last set of brackets on ground slag only if it will be used. Further guidance on these quantities should be obtained from the Government testing laboratory.

NOTE Q: Sawing of transverse contraction joints is recommended because of appearance and ease of sealing. However, in the past much RCC pavement has been allowed to crack naturally without benefit of sawing. These natural cracks normally occur at 12 to 20 m (40 to 70 ft) spacing. Delete this paragraph if sawed joints are not being used and modify paragraph Sealing Joints and Cracks accordingly. The bracketed statement should be included if longitudinal construction joints are to be sawed and sealed. In the past, longitudinal construction joints have had no treatment except for routing and sealing if they open up to form a crack 3 mm (1/8 inch) or more wide. In general this has been a satisfactory approach.

NOTE R: Other curing materials, such as membrane curing compound or polyethylene sheets, are not recommended for use on RCC for several reasons. The tendency of the surface of the relatively dry RCC is to dry out before a curing compound or polyethylene sheet can be applied, effectively retarding the strength gain, possibly reducing the ultimate strength, and producing a weaker surface susceptible to raveling and spalling. Also, the relatively rough surface texture of RCC would require high dosages of curing compound (double) to create a void-free membrane.

NOTE S: For record, nuclear density gauge readings of moisture content and density should be taken at 50 mm (2-inch) intervals to the thickness of the pavement minus 50 mm (2 inches), although the deepest reading only will be the basis for acceptance. The deepest readings of the nuclear density gauges of the Contractor and Government should be checked for agreement.

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-- End of Section --